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Sengun et al.

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(54) **SURGICAL FILAMENT SNARE ASSEMBLIES**

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This patent is subject to a terminal disclaimer.

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A61B 90/00 (2016.01)
A61B 17/06 (2006.01)

(52) **U.S. Cl.**

CPC ***A61B 17/0401*** (2013.01); ***A61B 17/06166*** (2013.01); *A61B 17/0482* (2013.01);

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(58) **Field of Classification Search**

CPC A61B 17/0401; A61B 2017/0414; A61B 2017/0445

(Continued)

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(57) **ABSTRACT**

A surgical filament snare assembly including an anchor capable of being fixated in bone and having a filament engagement feature. A first filament has a noose with first and second noose limbs connected, preferably slidably connected, to the filament engagement feature of the anchor. The first and second noose limbs emerge from the anchor as first and second free filament limbs which are capable of being passed through tissue to be repaired and then passable through the noose. The noose, such as one or more half-hitches, is capable of receiving the free filament limbs and strangulating them when tension is applied to at least one of the free filament limbs and the noose to enable incremental tensioning of the tissue after the anchor is fixated. Preferably, the snare assembly further includes a flexible sleeve joining at least some portion of the first and second free

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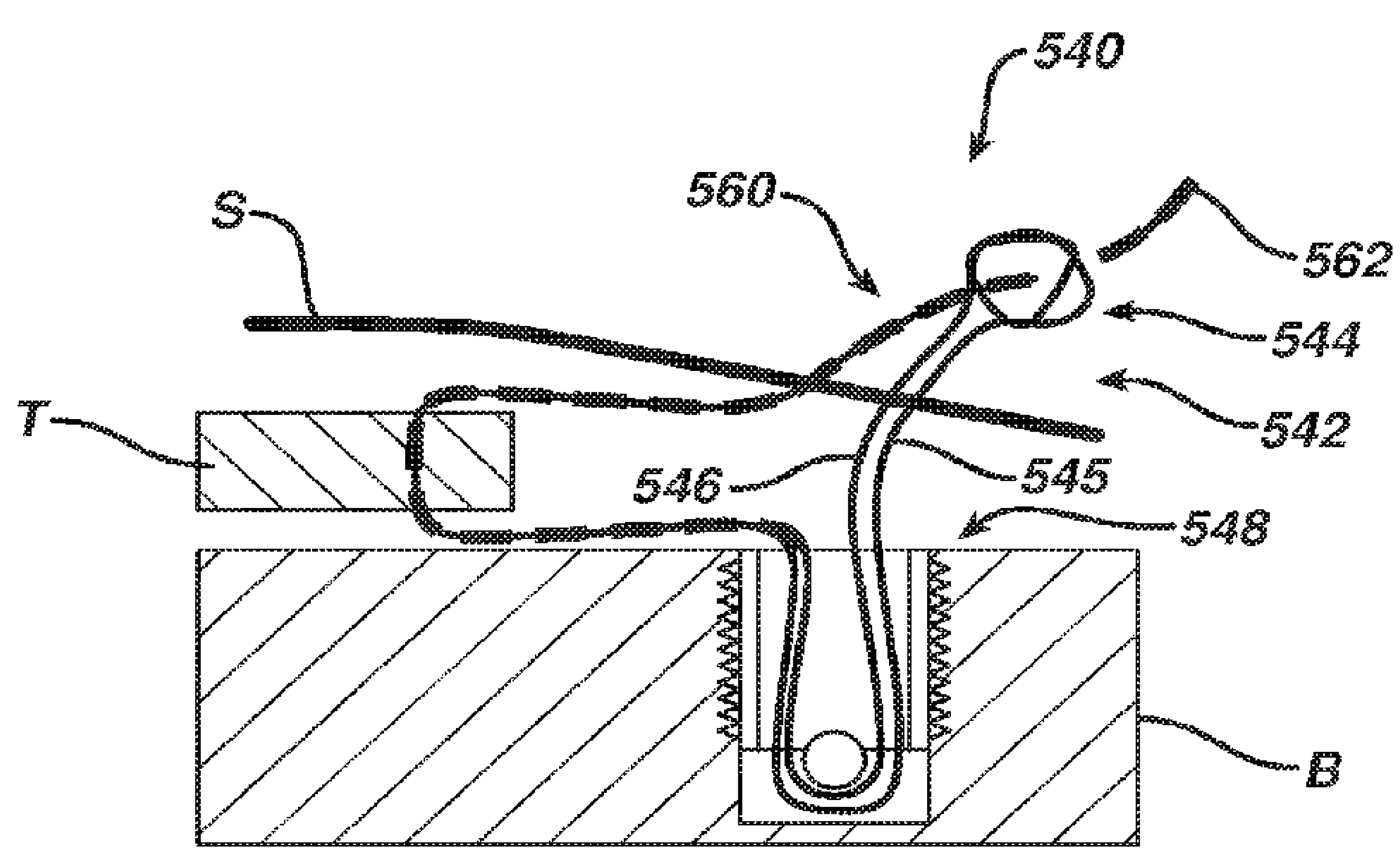

filament limbs to facilitate passing of the free filament limbs at least through the tissue as a single unit.

12 Claims, 26 Drawing Sheets

Related U.S. Application Data

continuation-in-part of application No. 12/977,146, filed on Dec. 23, 2010, now Pat. No. 8,821,543, and a continuation-in-part of application No. 12/977,154, filed on Dec. 23, 2010, now Pat. No. 8,814,905.

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(58) **Field of Classification Search**
USPC 606/60, 139, 145, 148, 228, 230, 300
See application file for complete search history.

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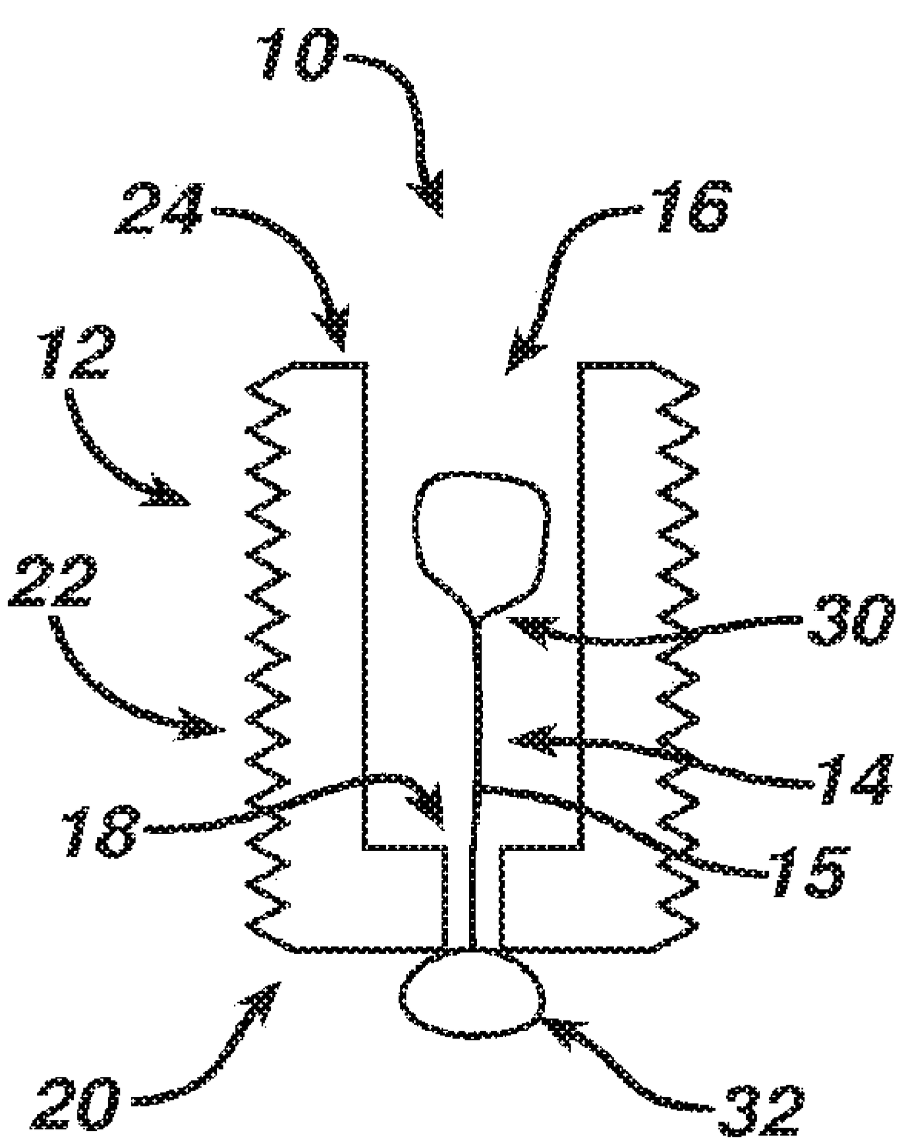

FIG. 1

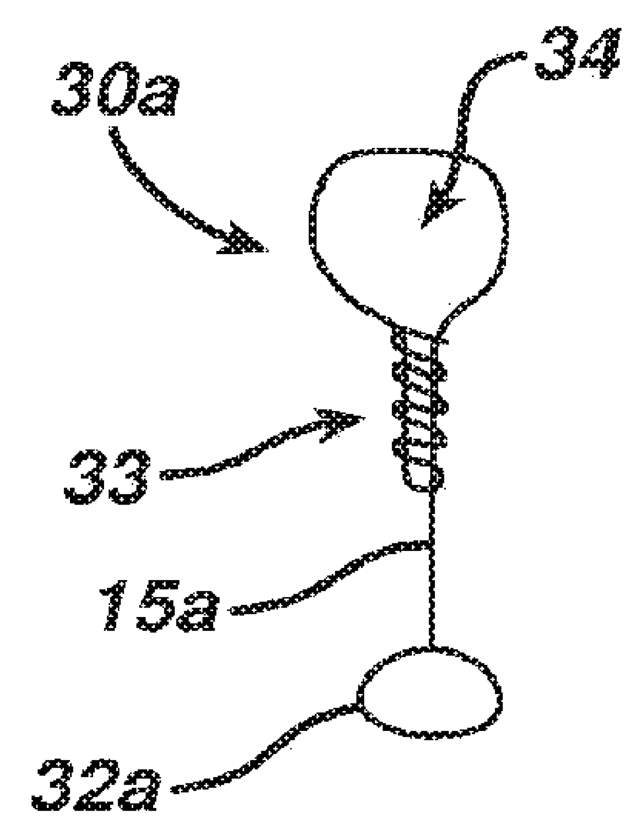

FIG. 1A

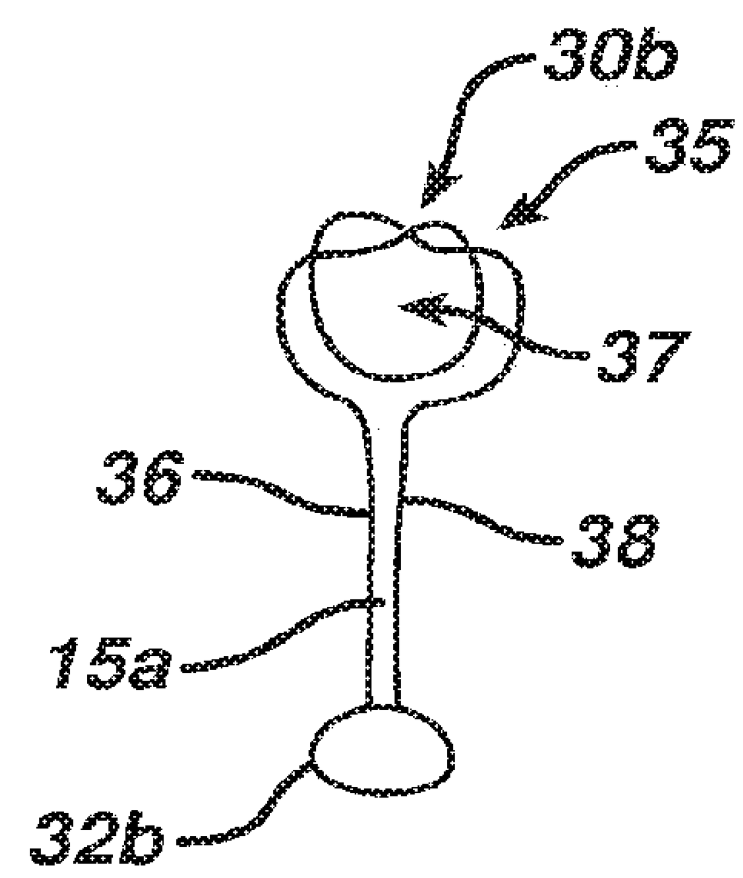

FIG. 1B

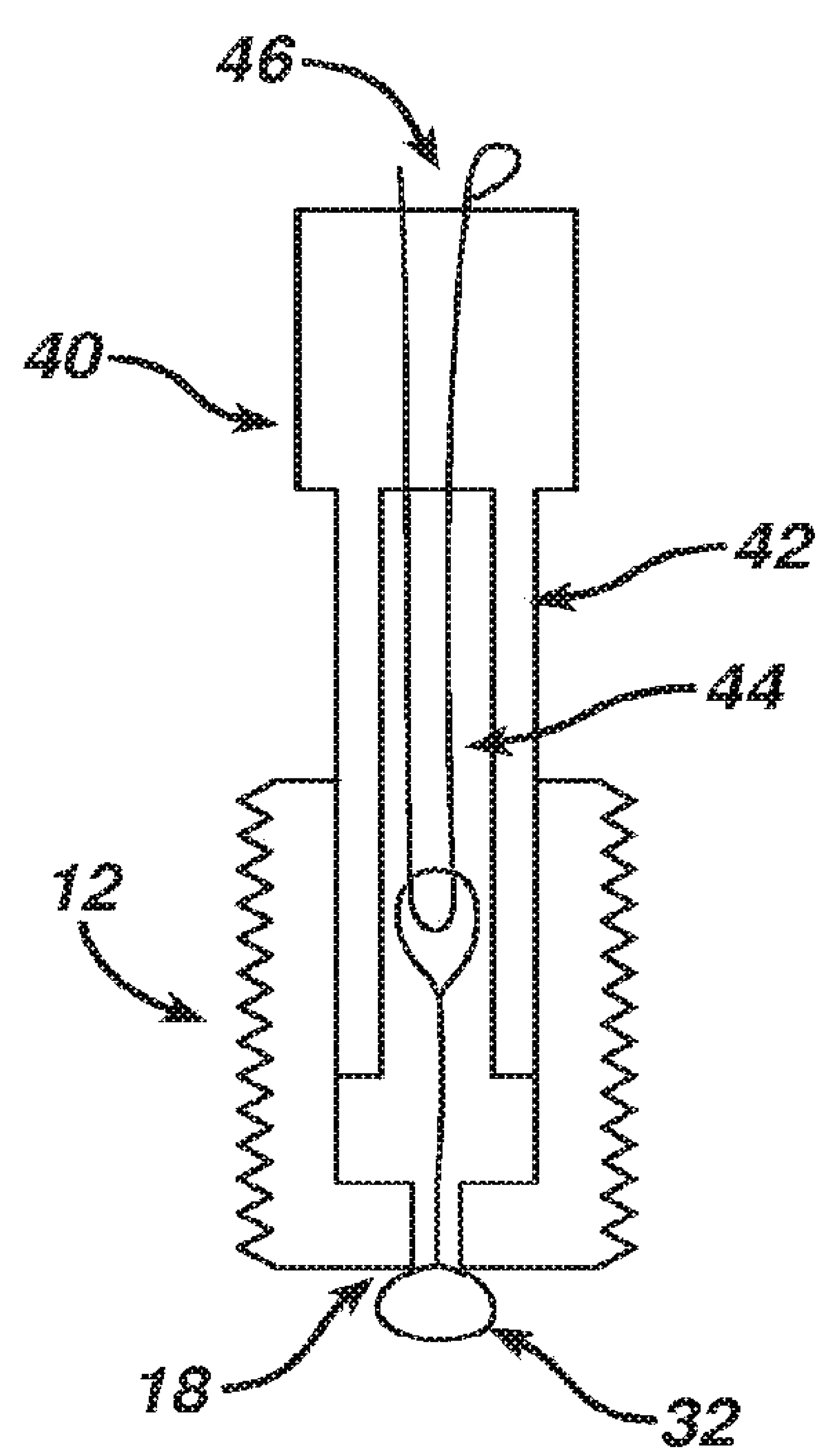

FIG. 2

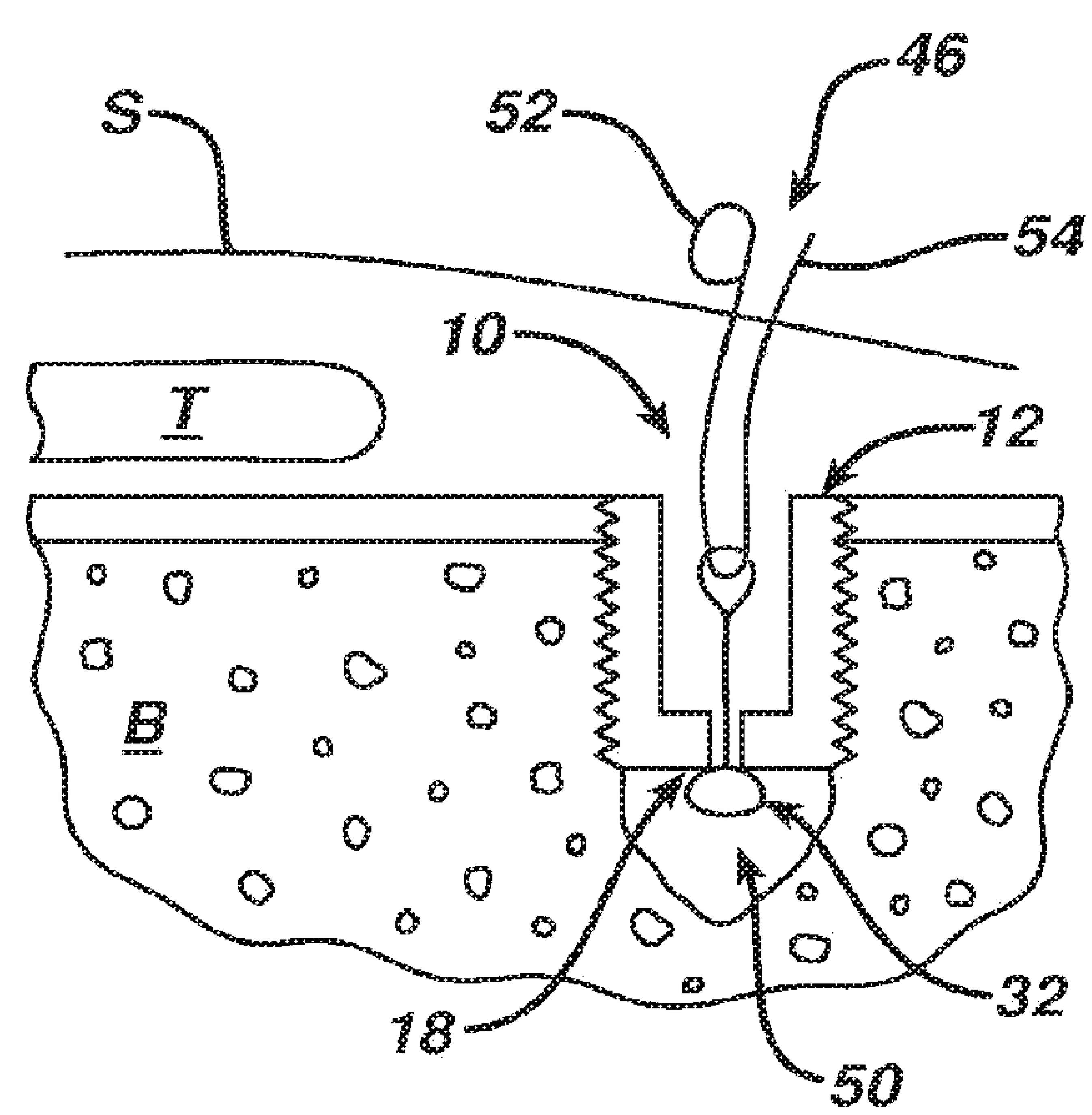

FIG. 3

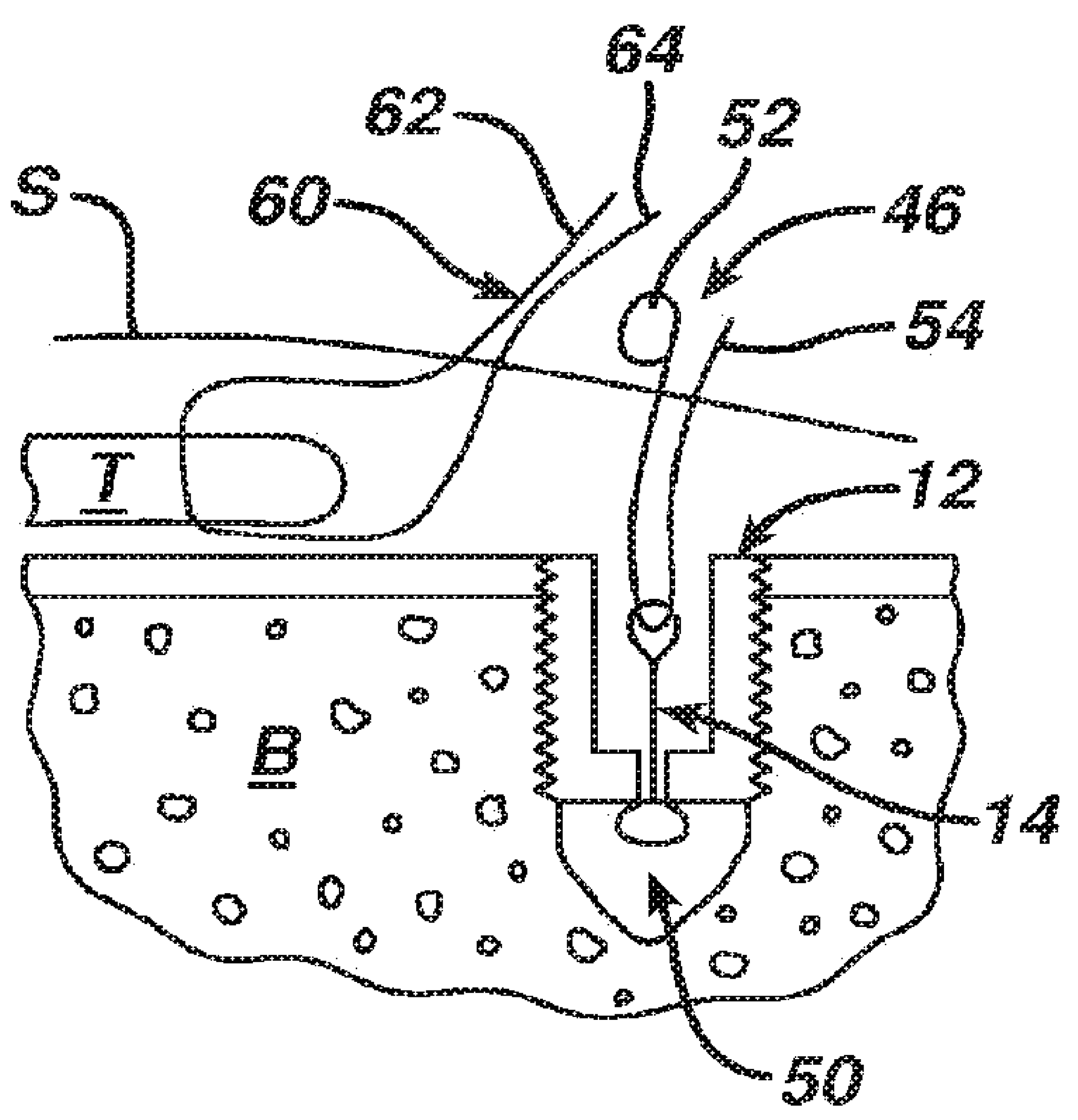

FIG. 4

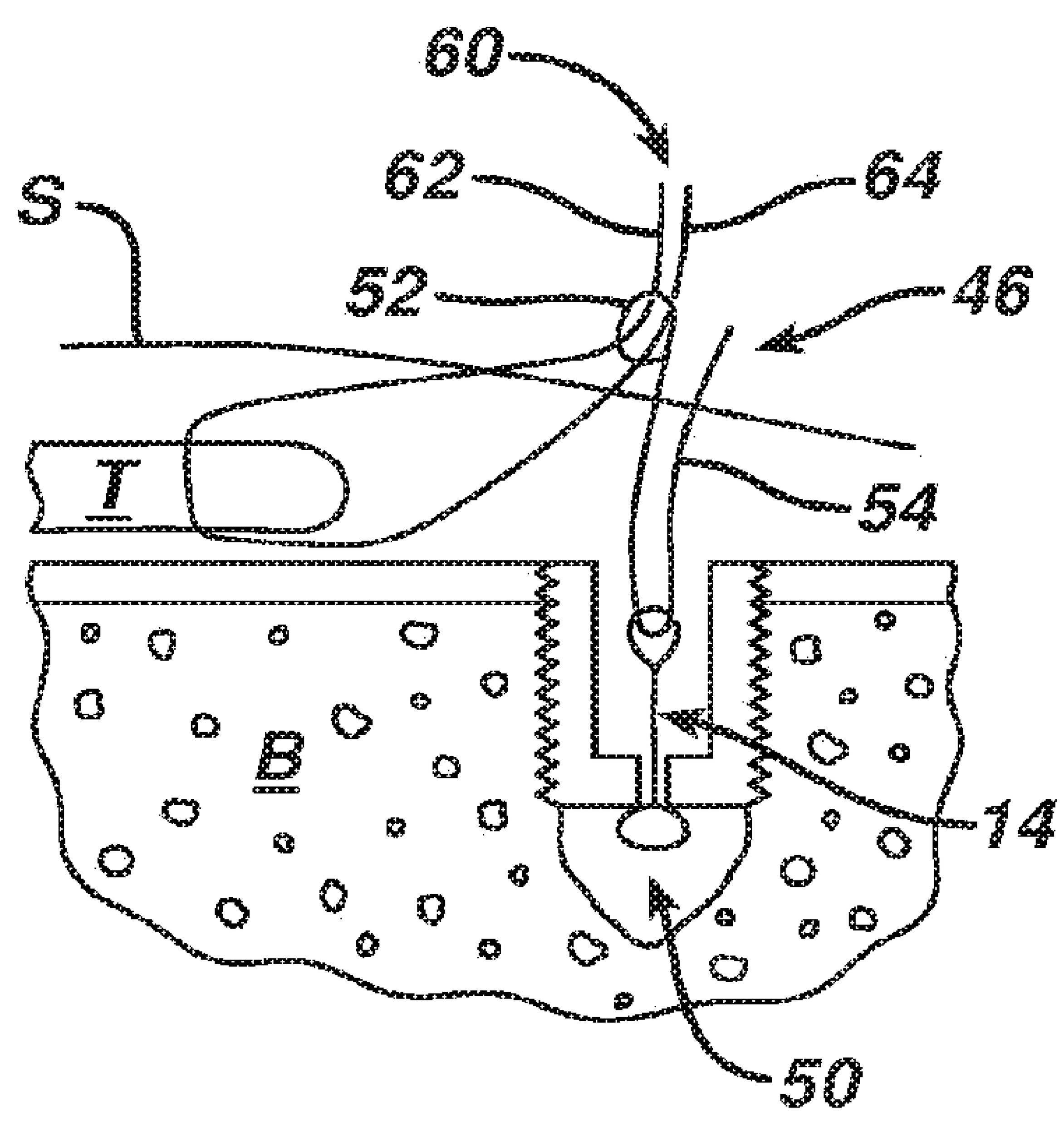

FIG. 5

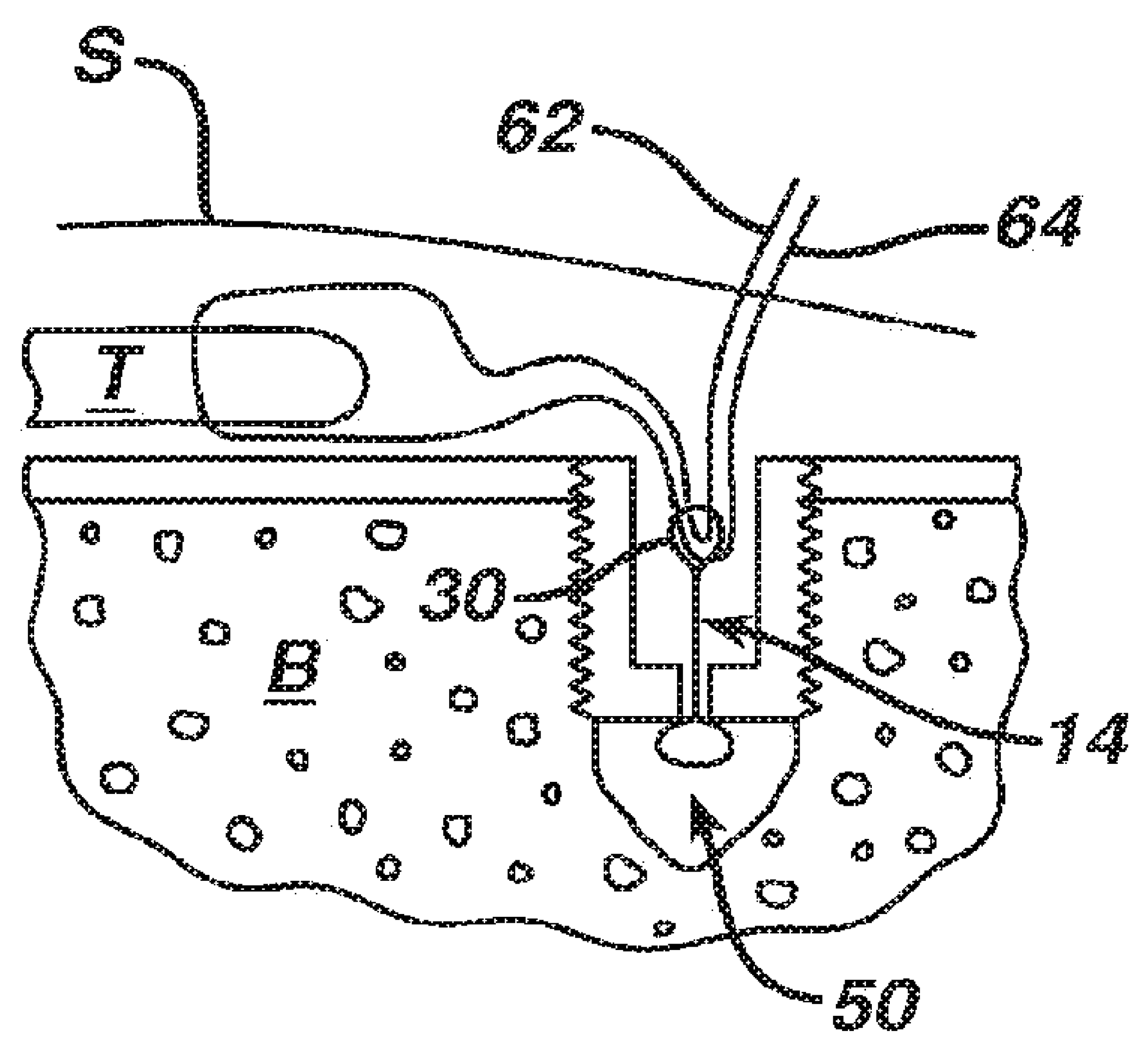

FIG. 6

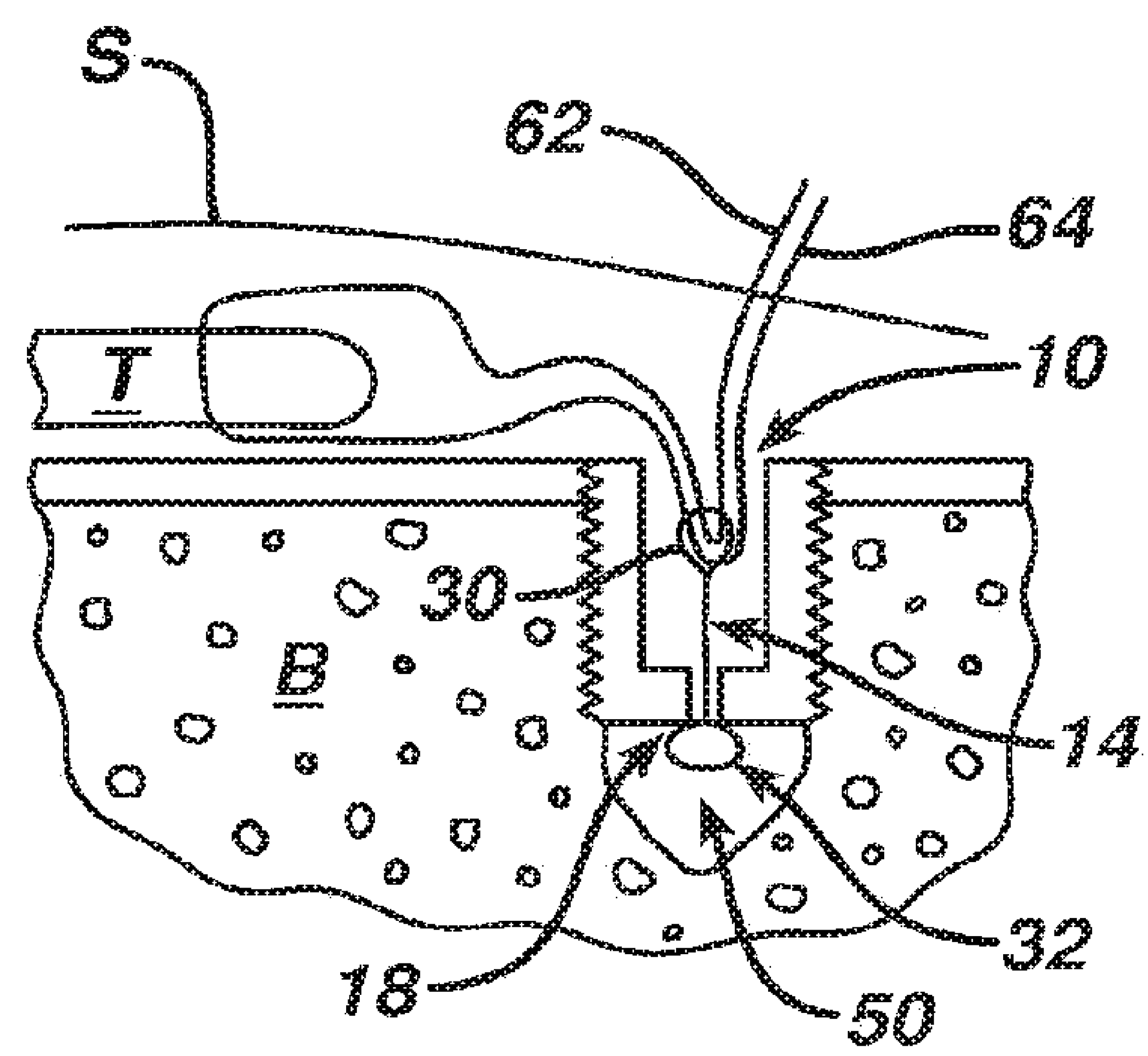

FIG. 7

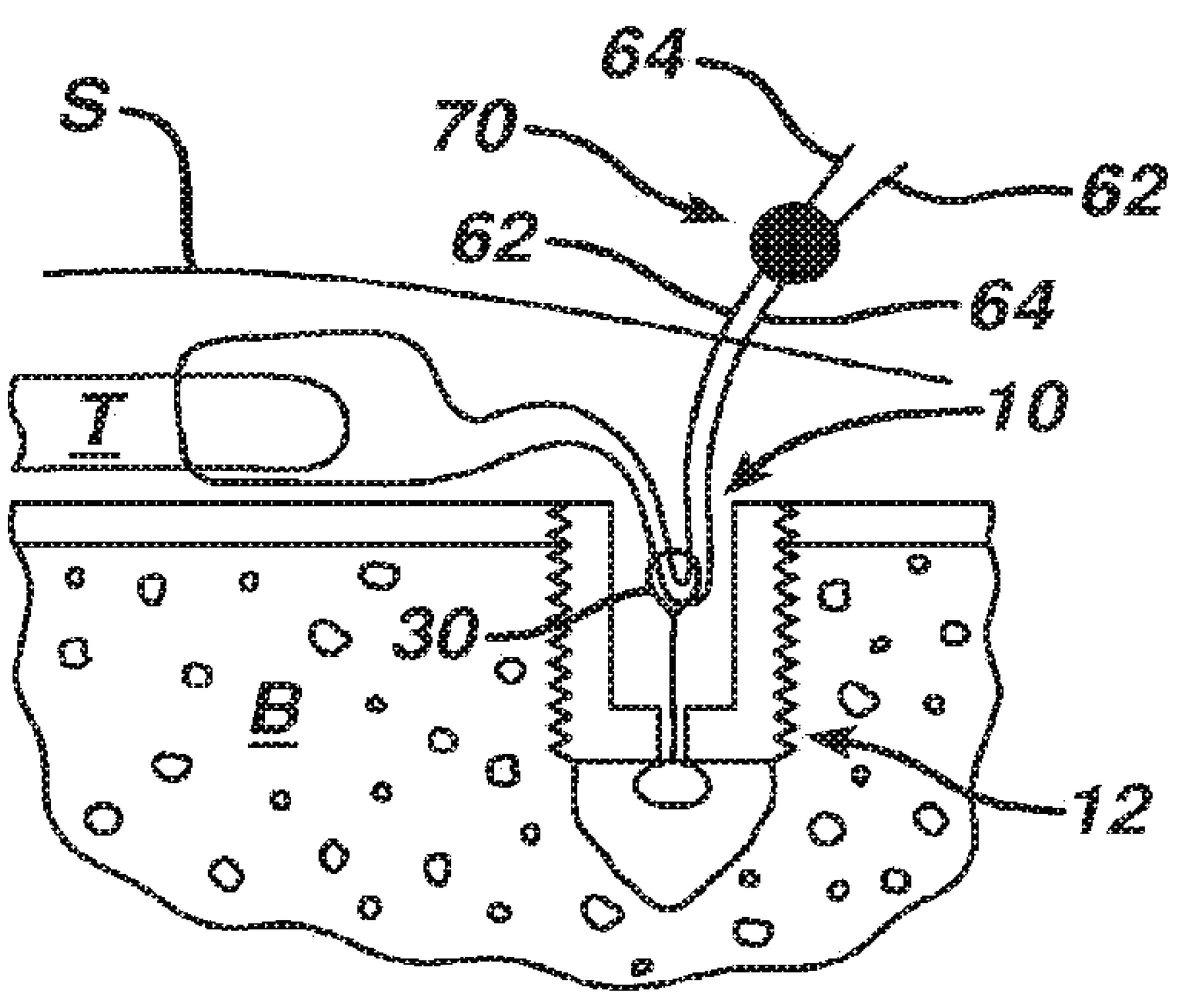

FIG. 8

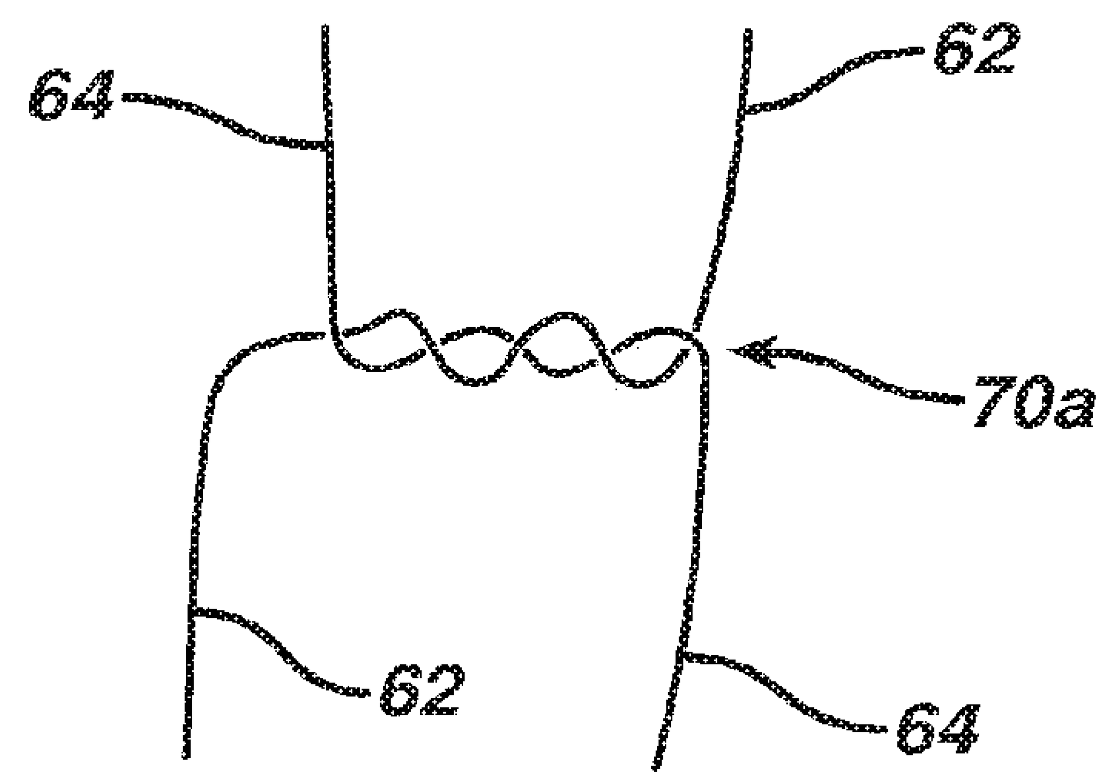

FIG. 8A

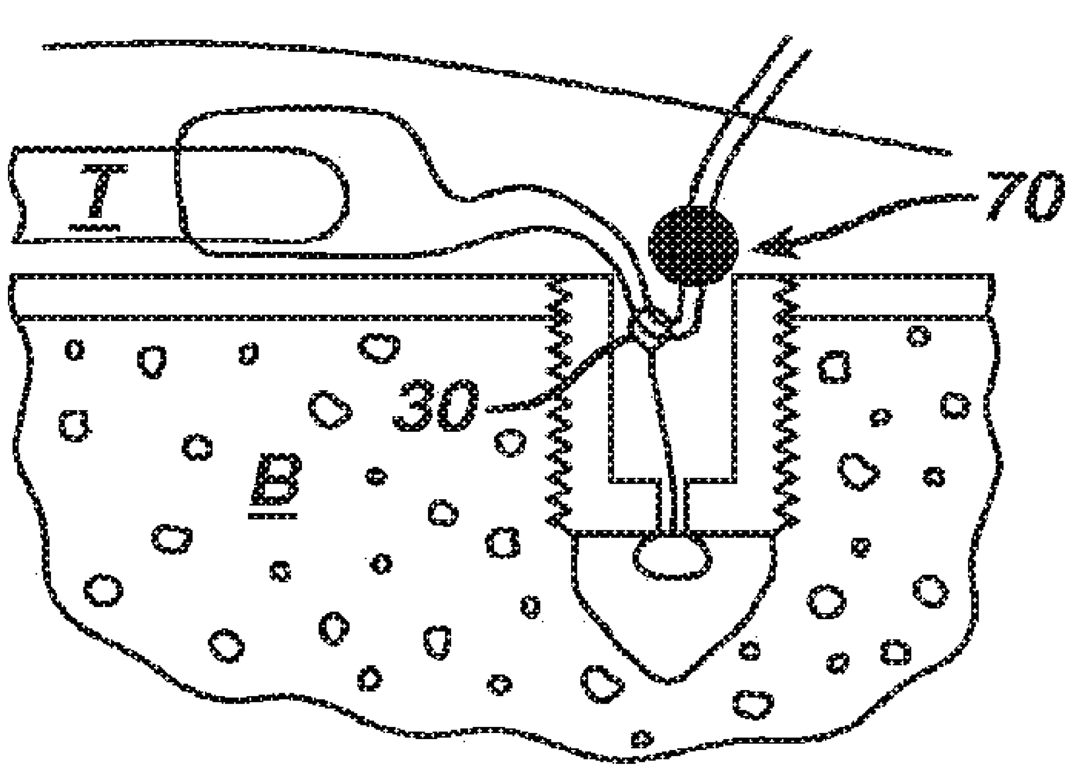

FIG. 9

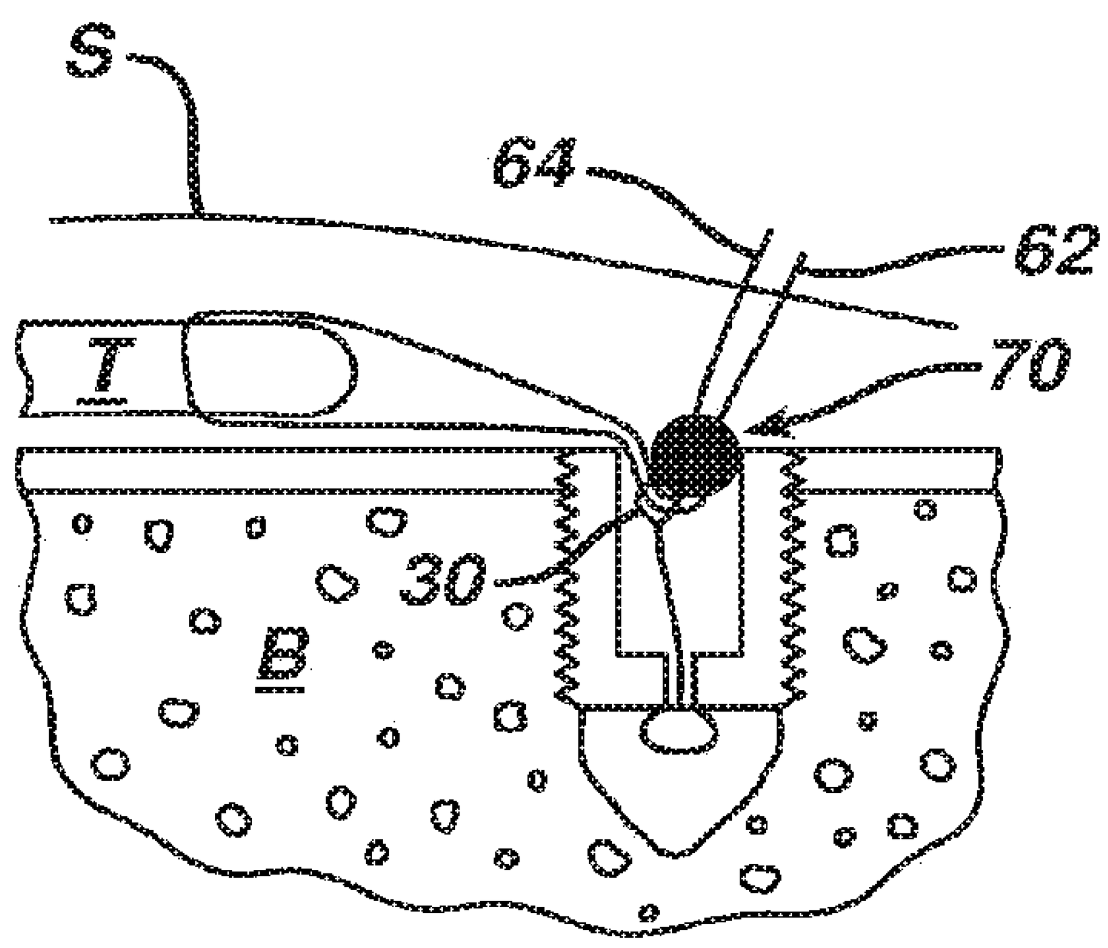

FIG. 10

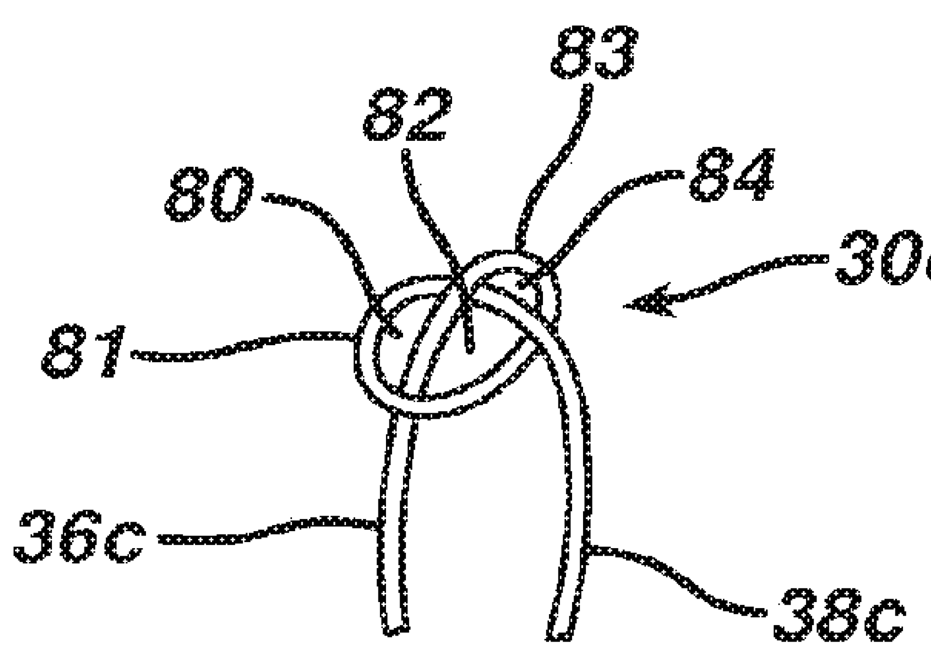

FIG. 11

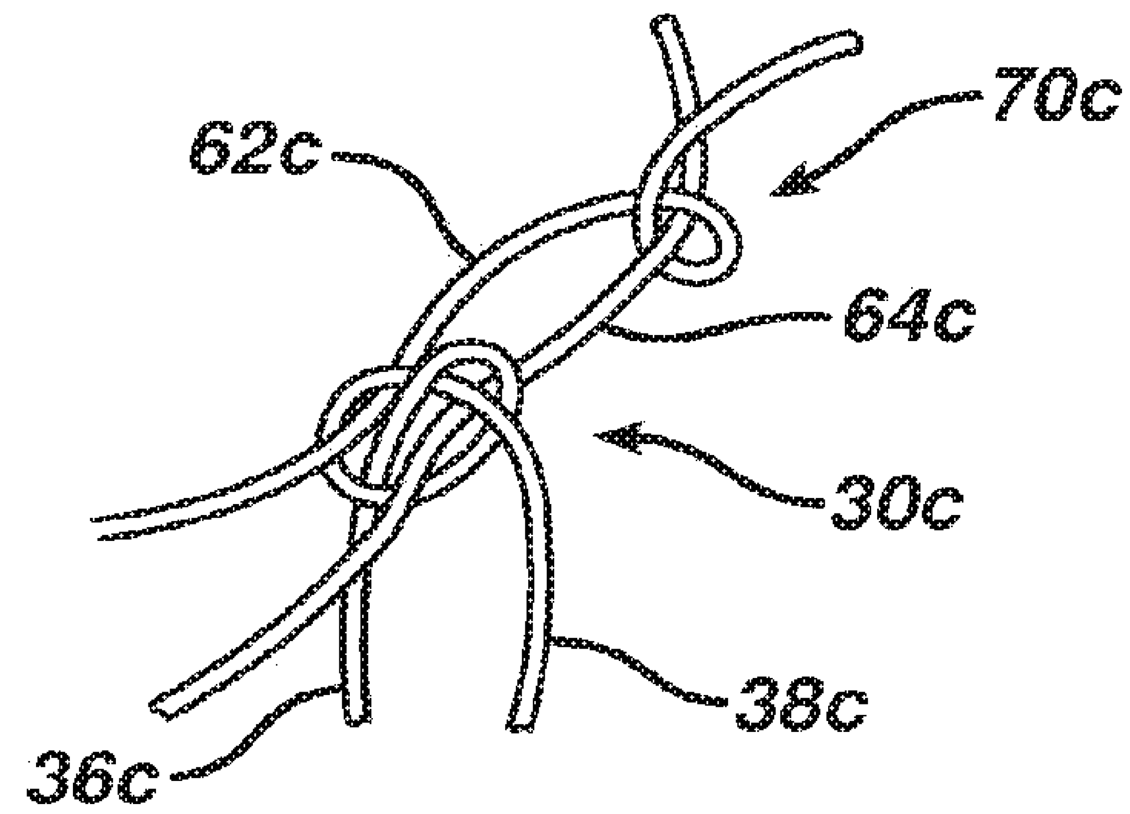

FIG. 12

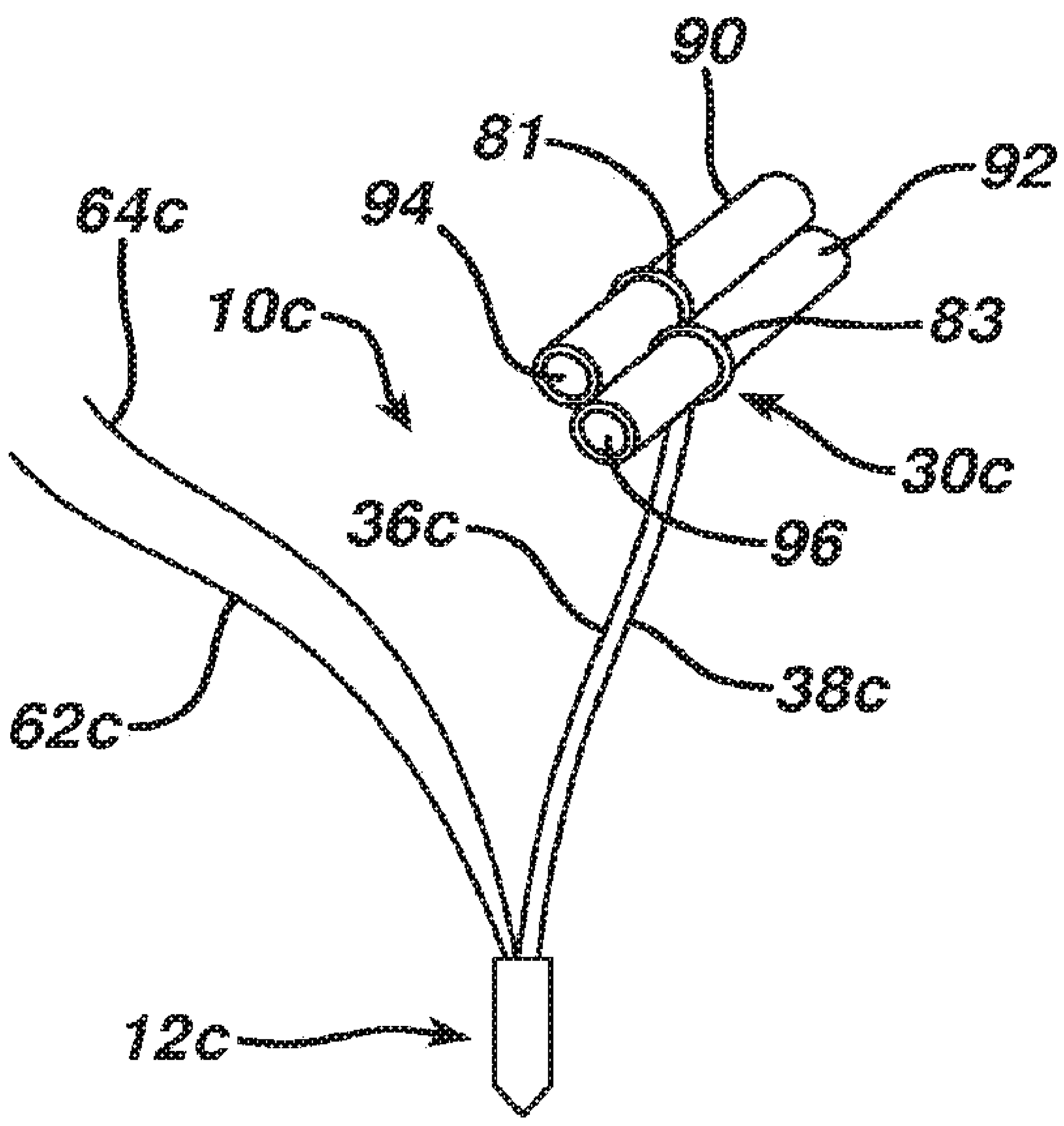

FIG. 13

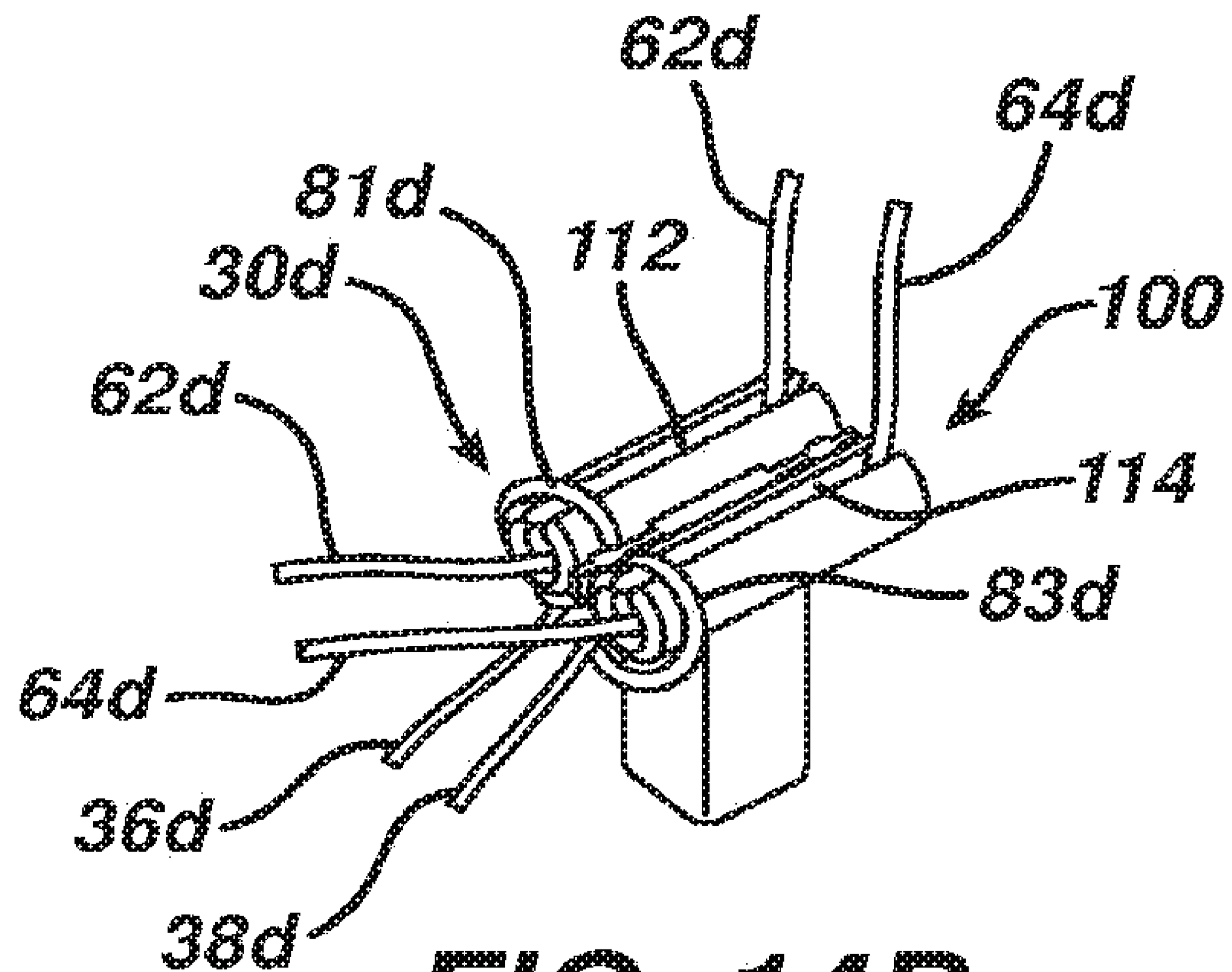

FIG. 14B

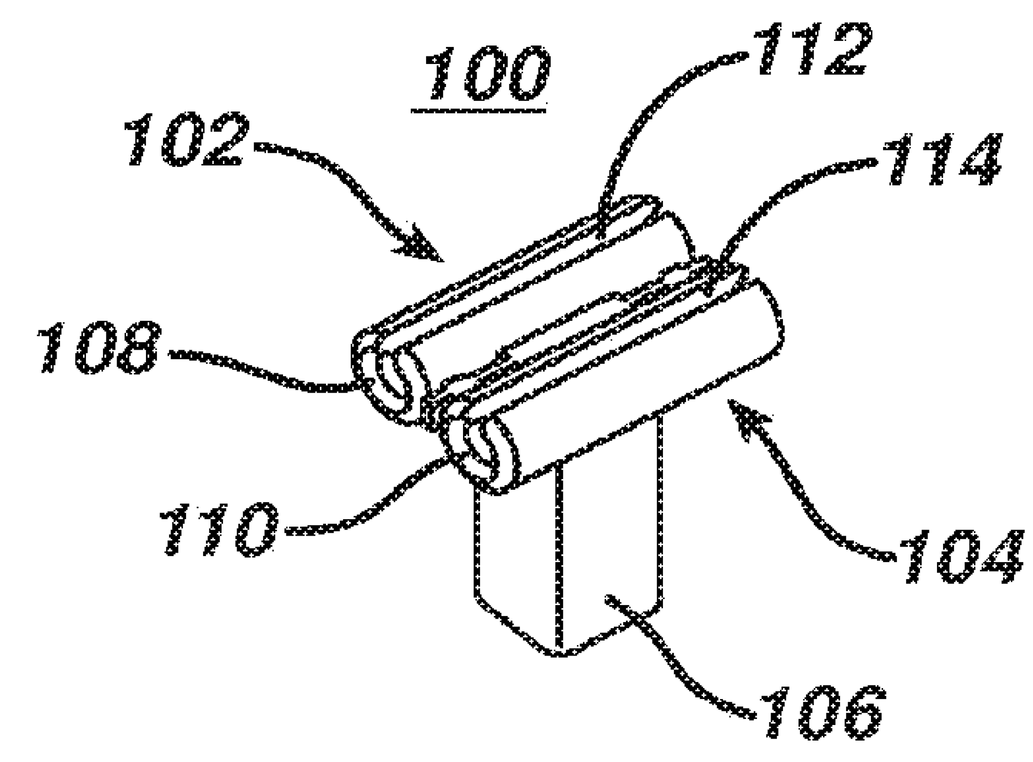

FIG. 14A

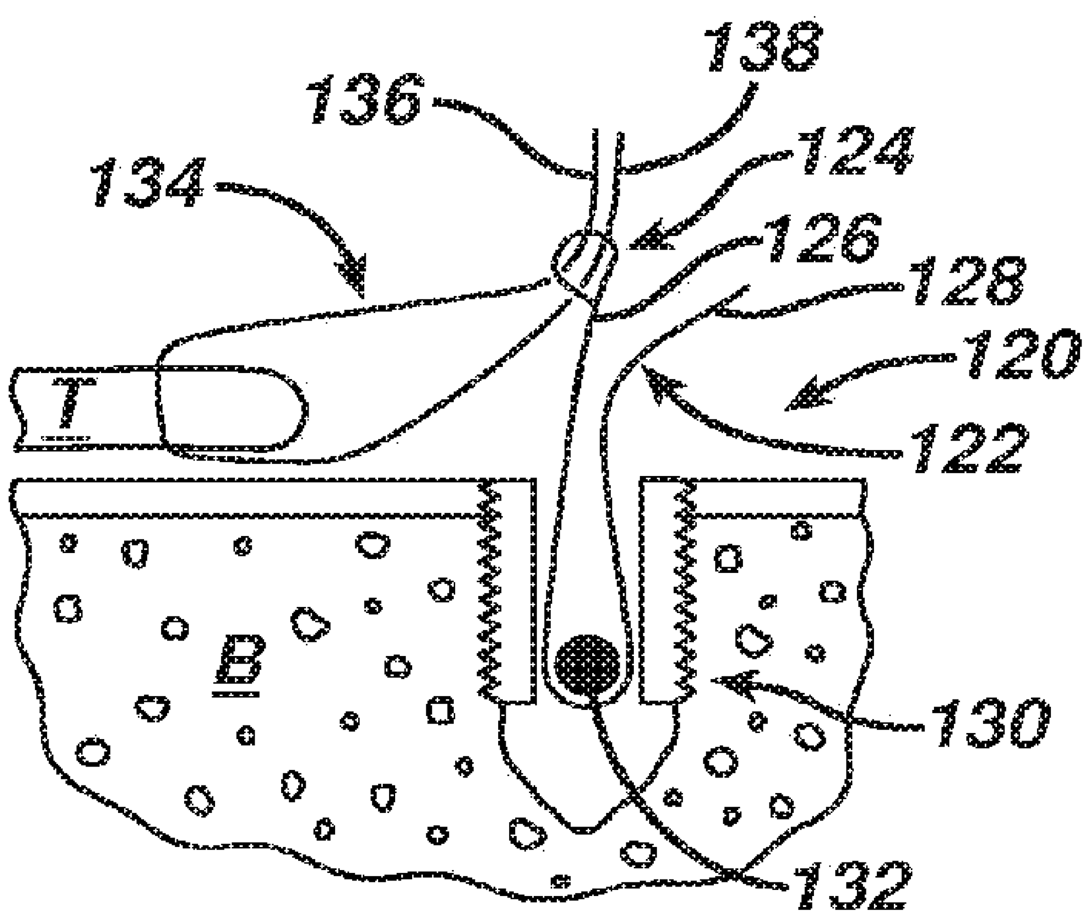

FIG. 15

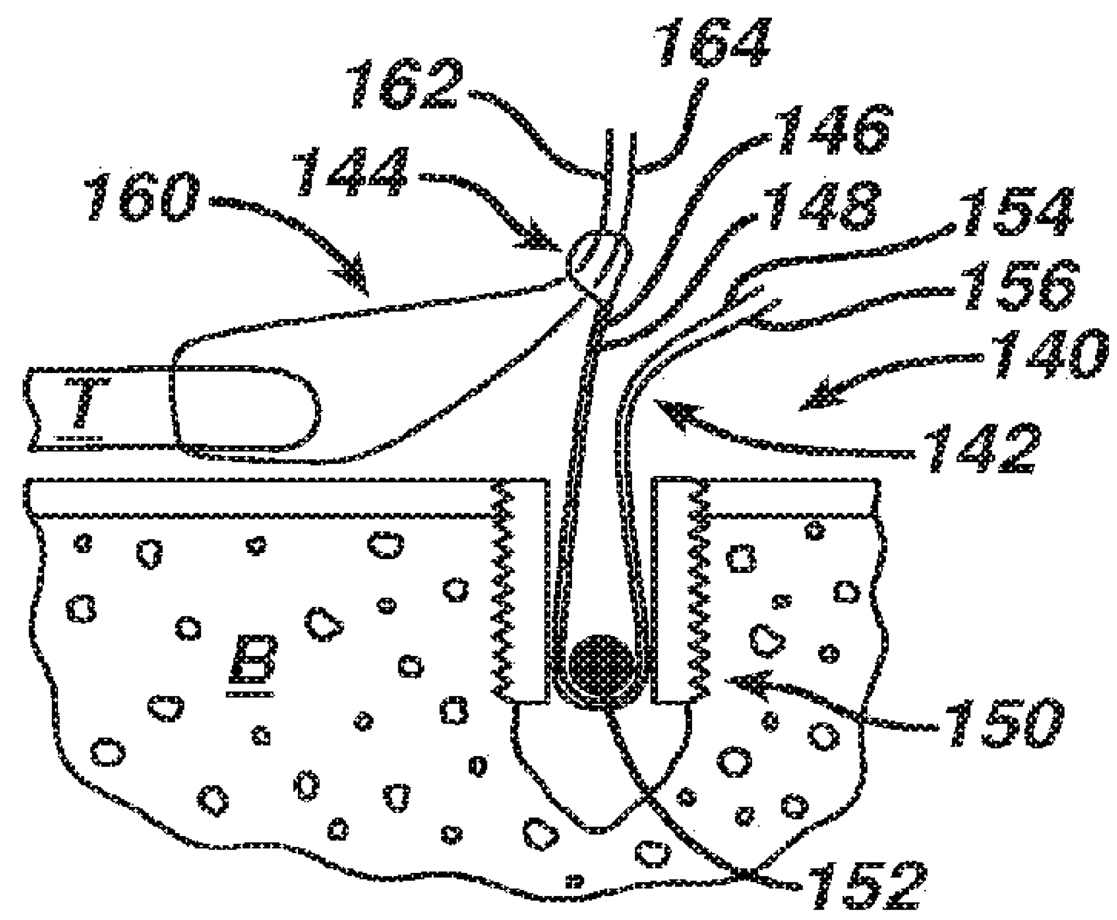

FIG. 16

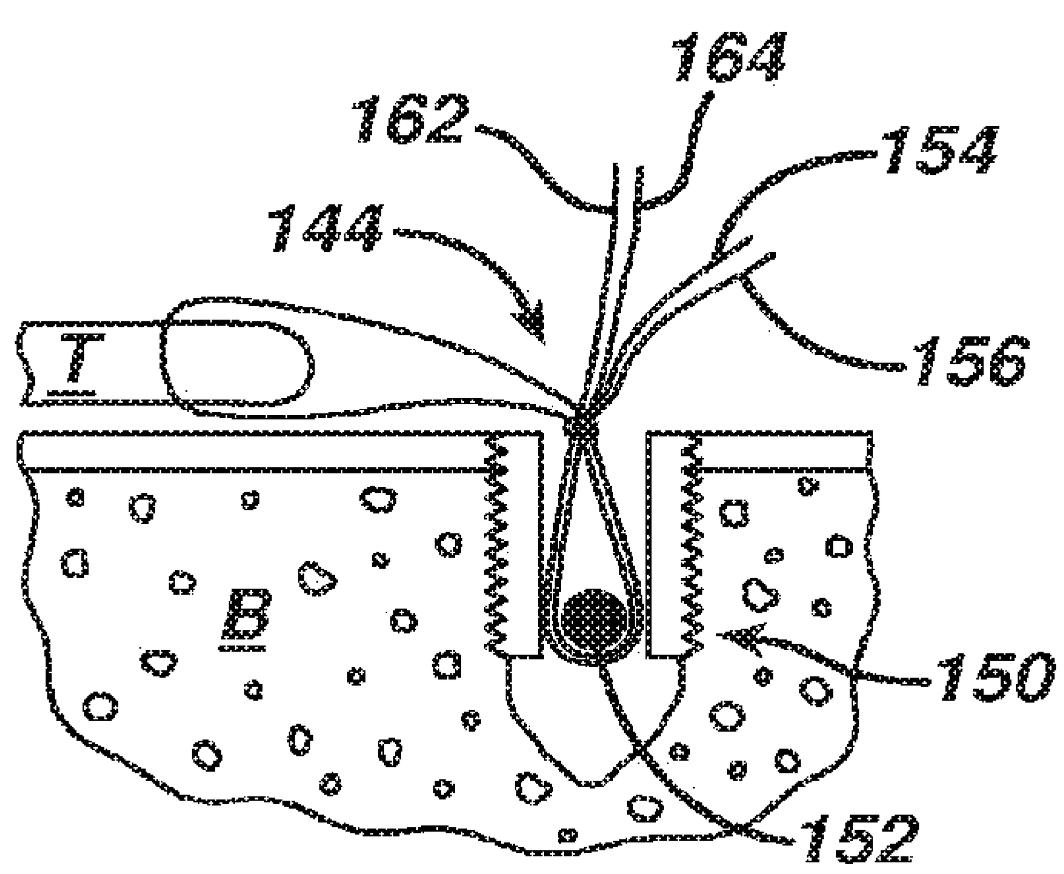

FIG. 16A

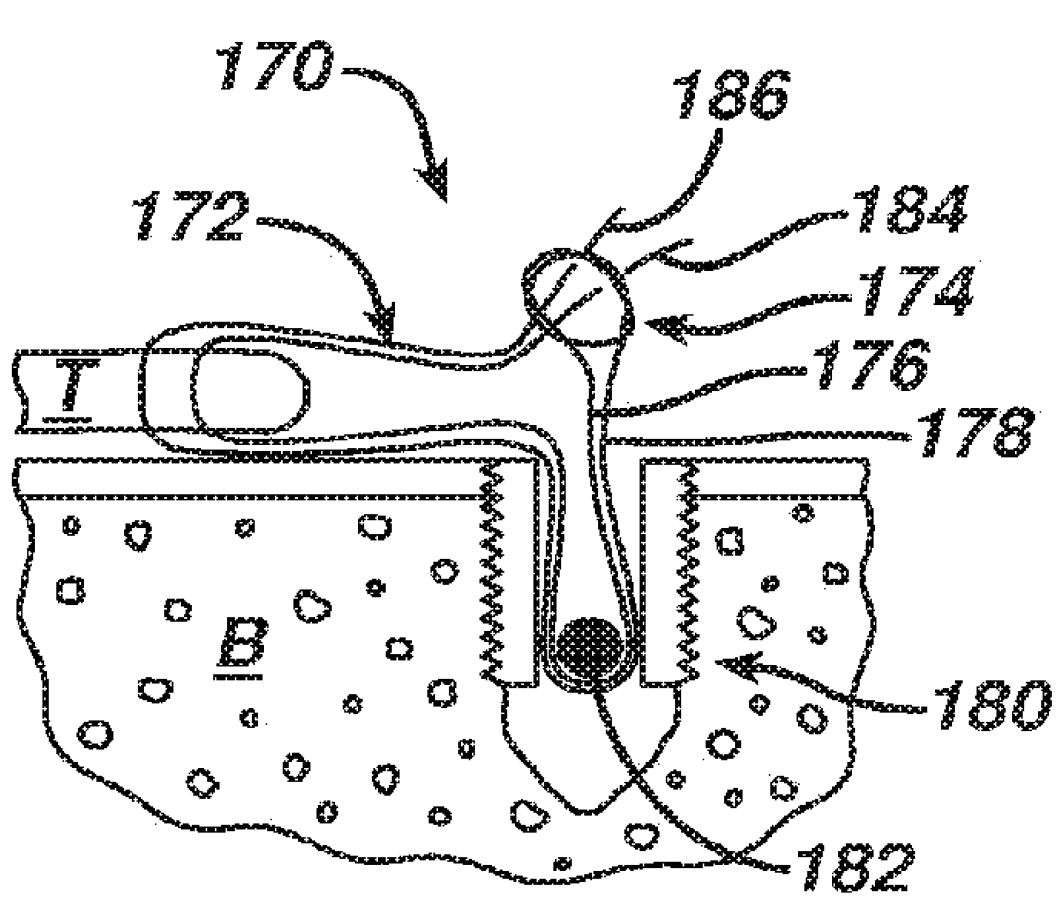

FIG. 17

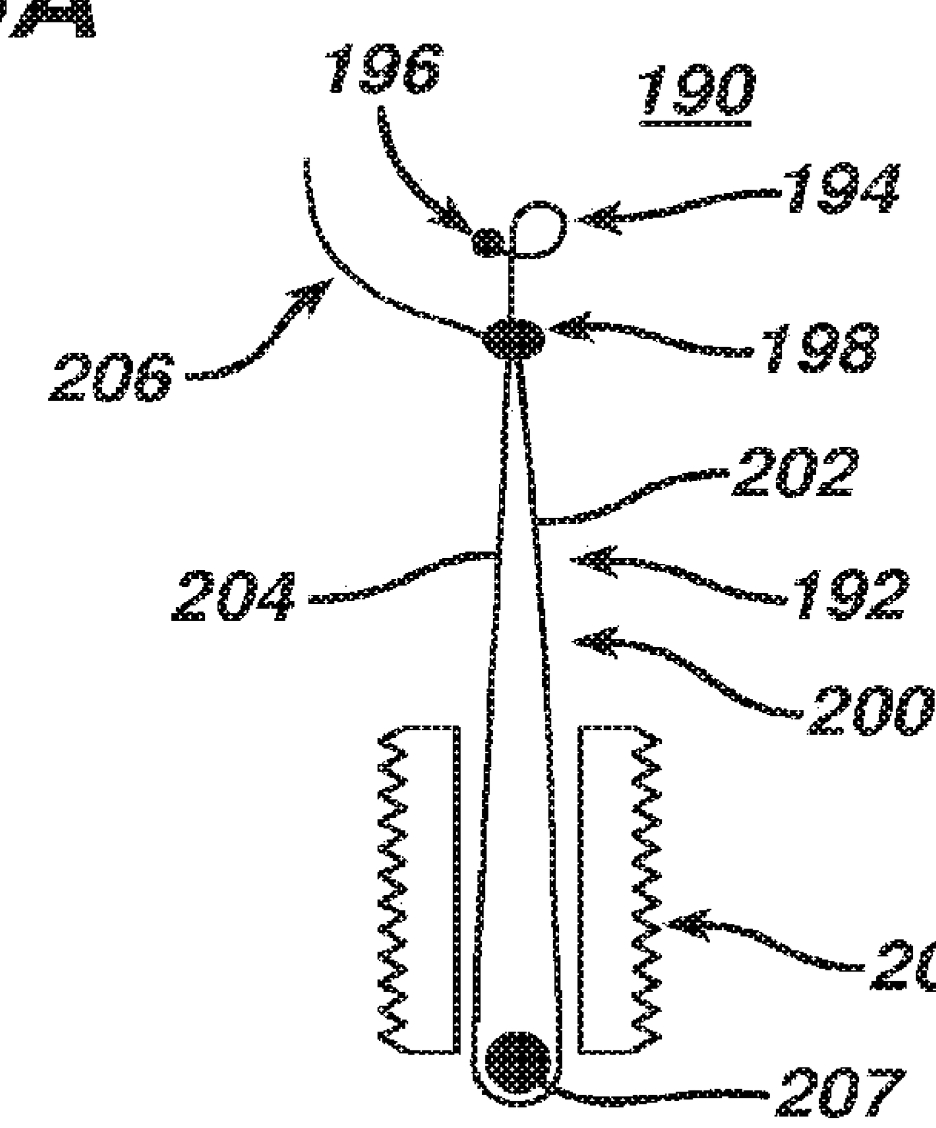

FIG. 18

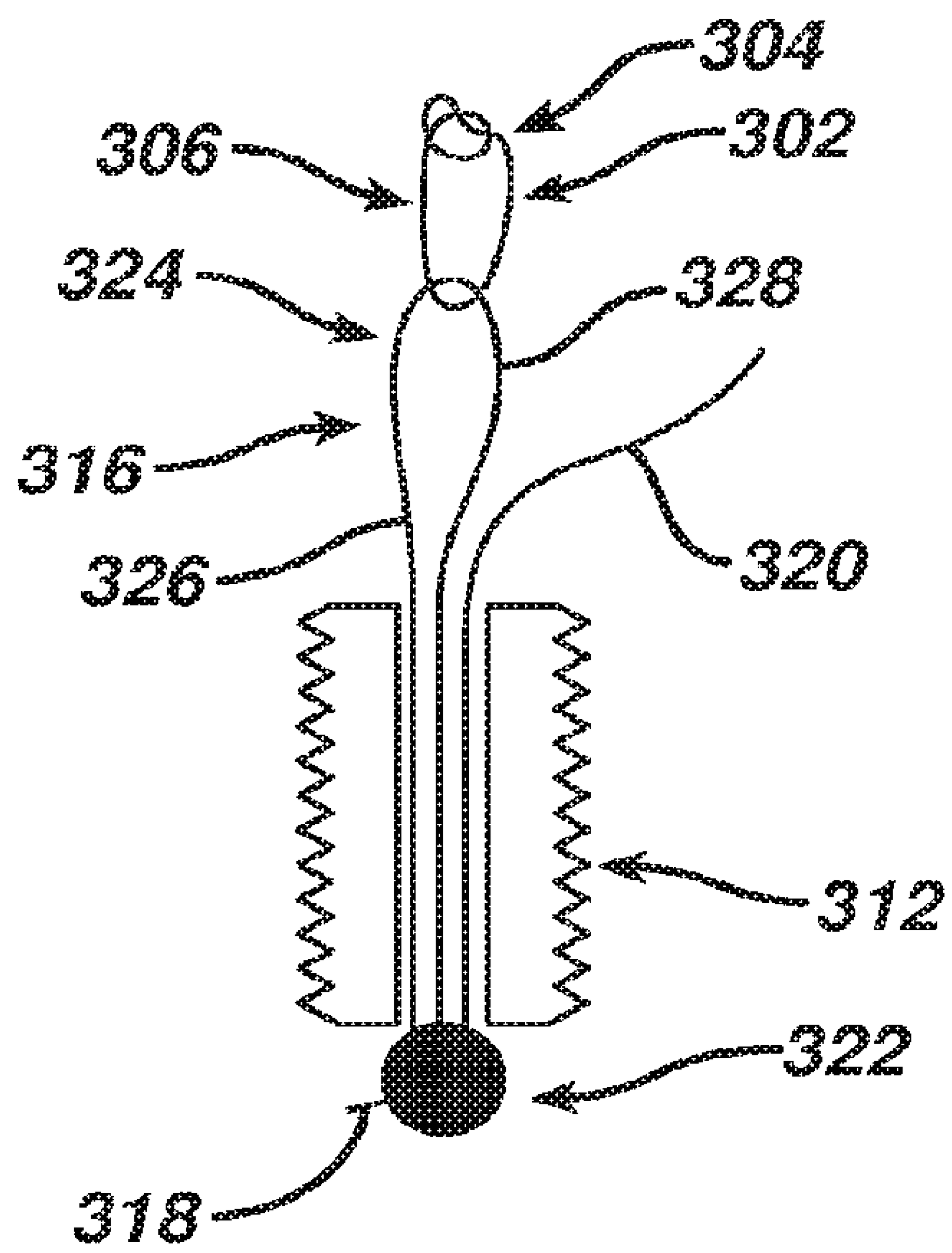

FIG. 19

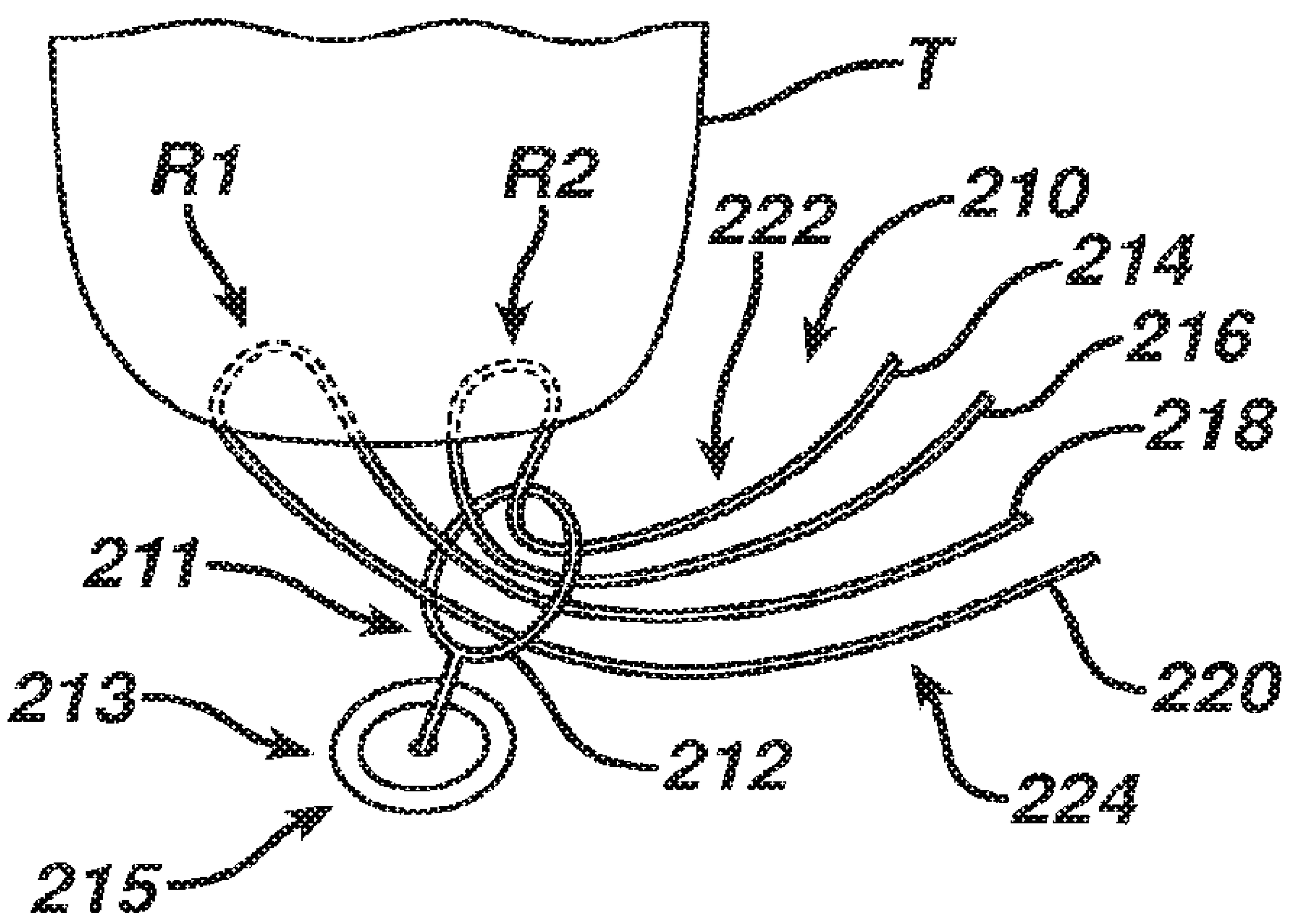

FIG. 20

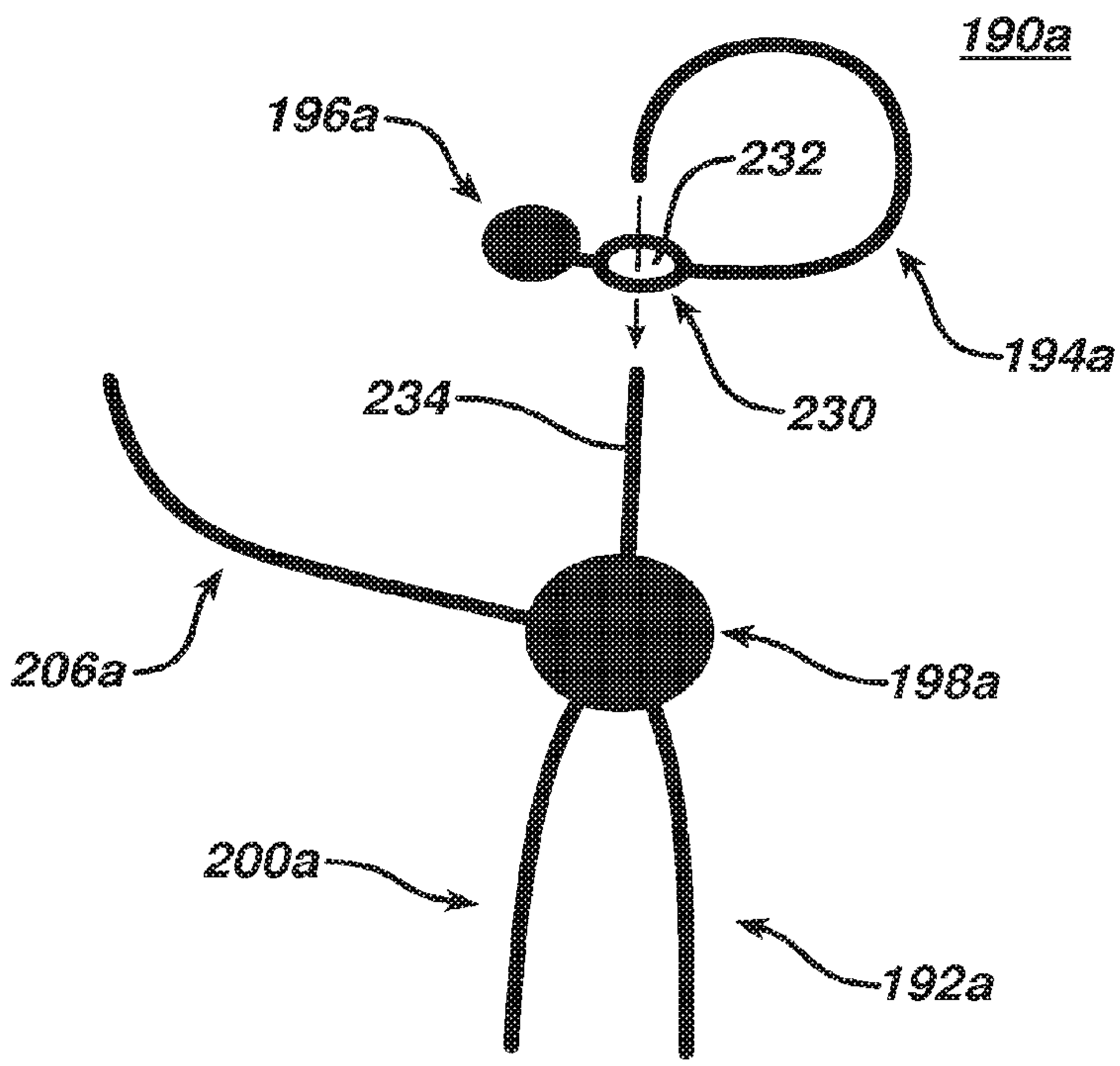

FIG. 21

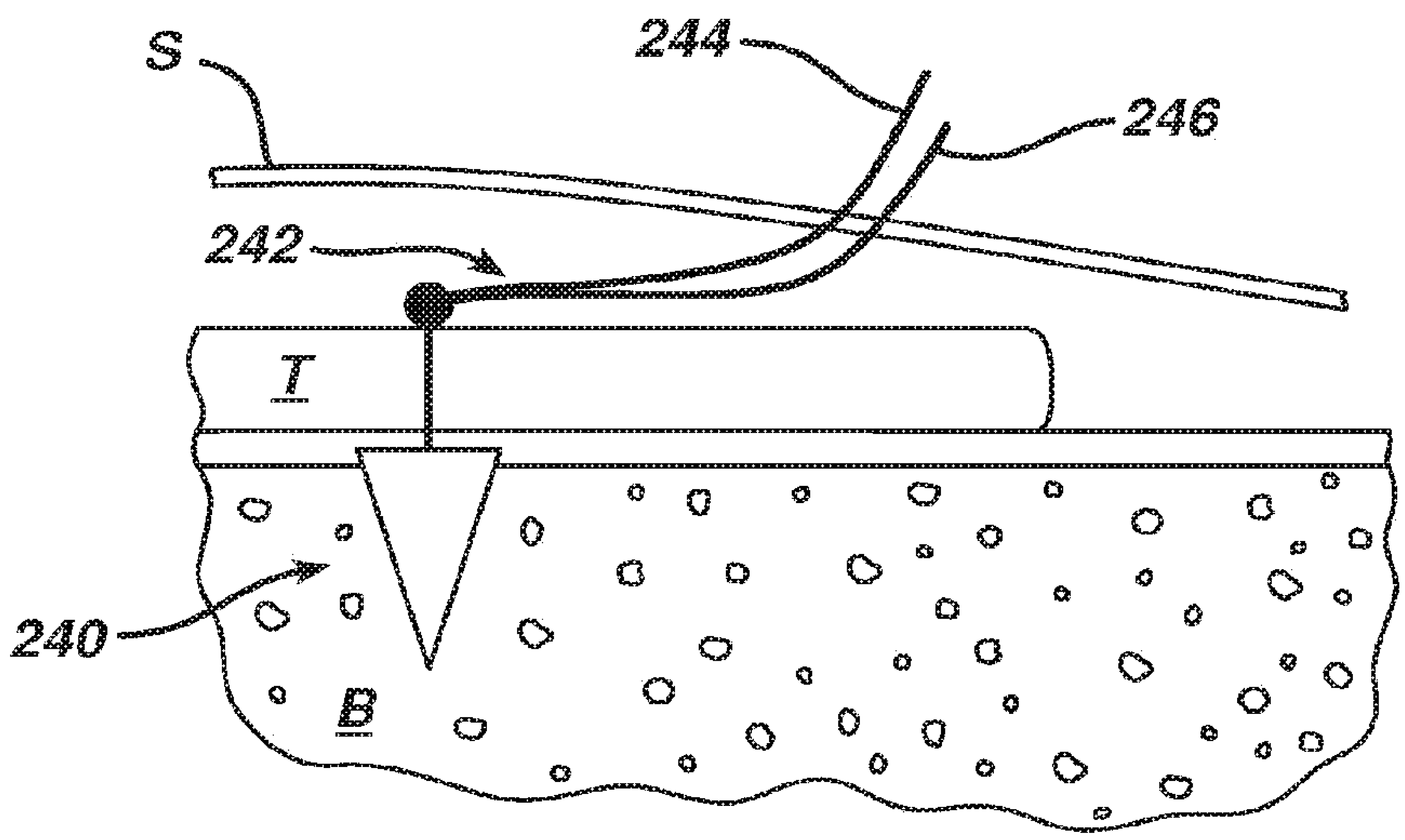
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FIG. 22

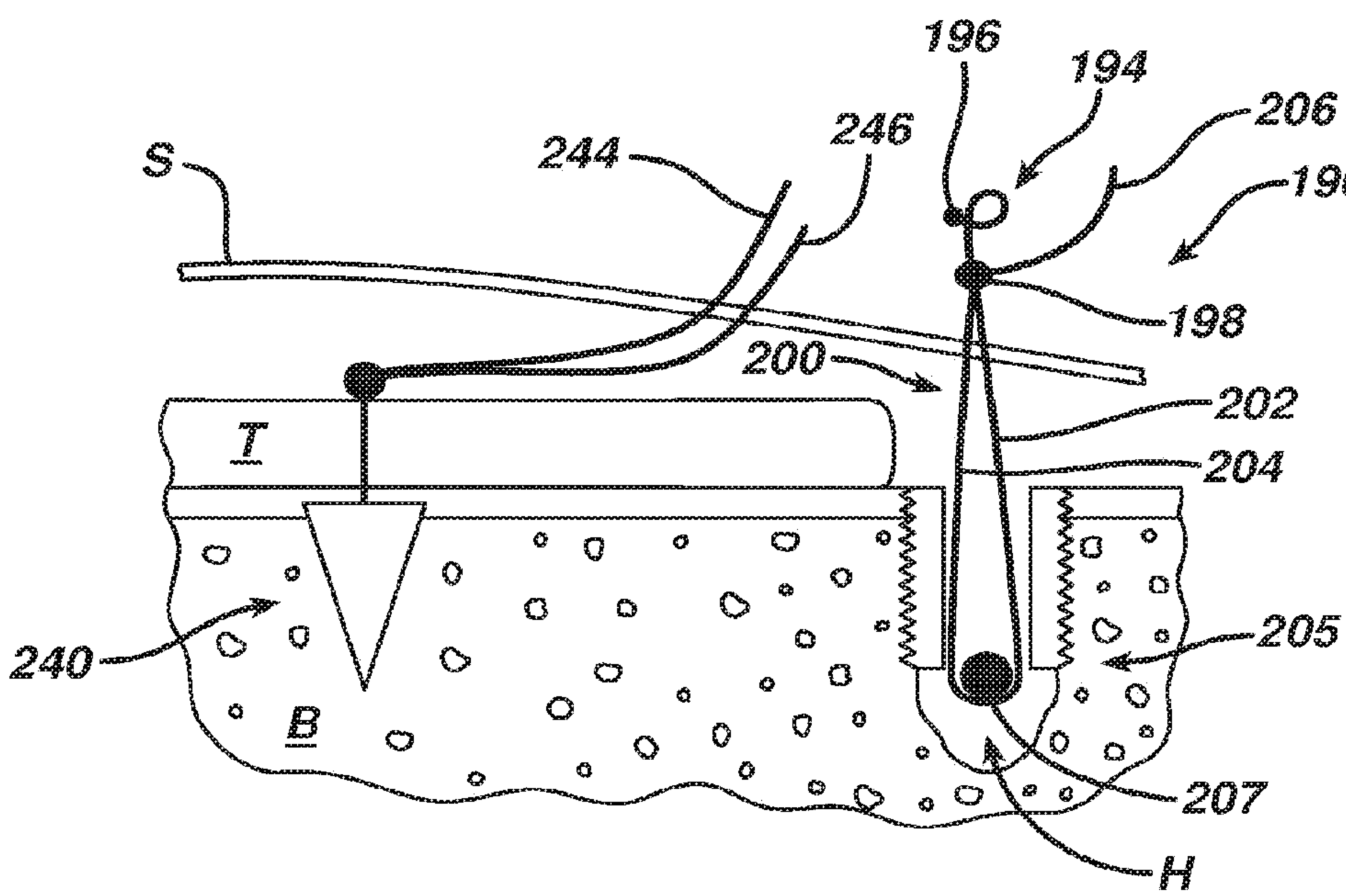
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FIG. 23

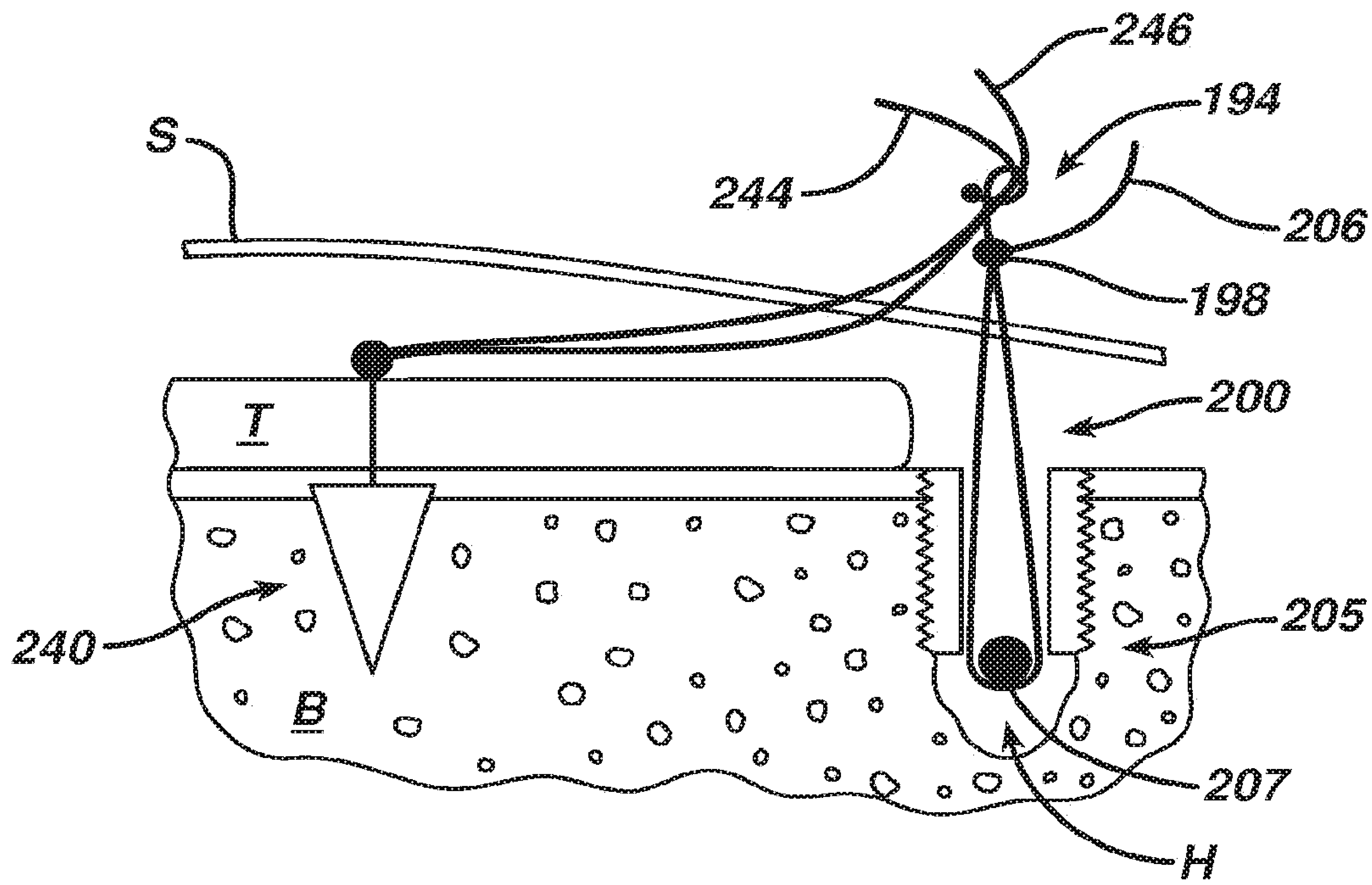
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FIG. 24

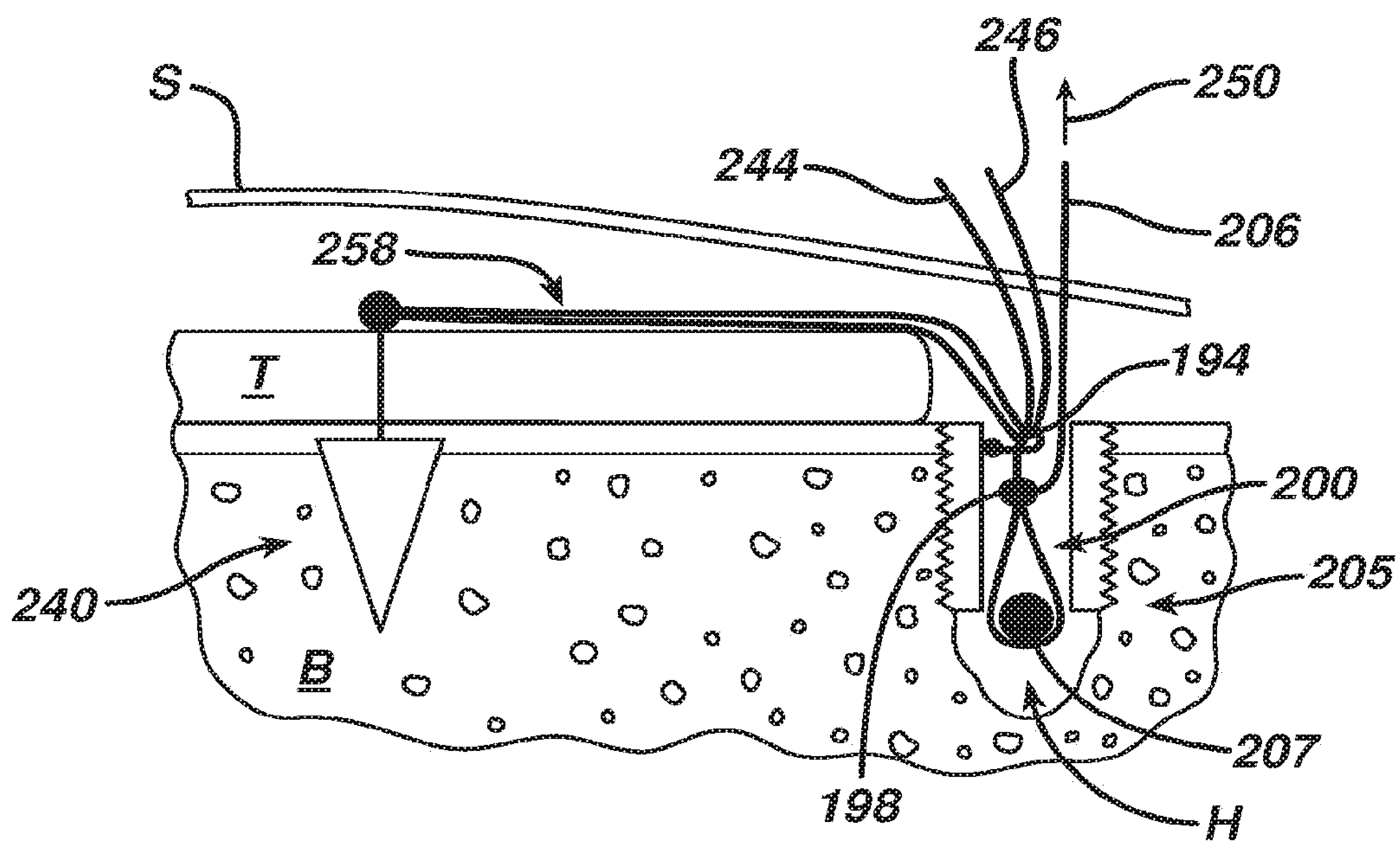
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FIG. 25

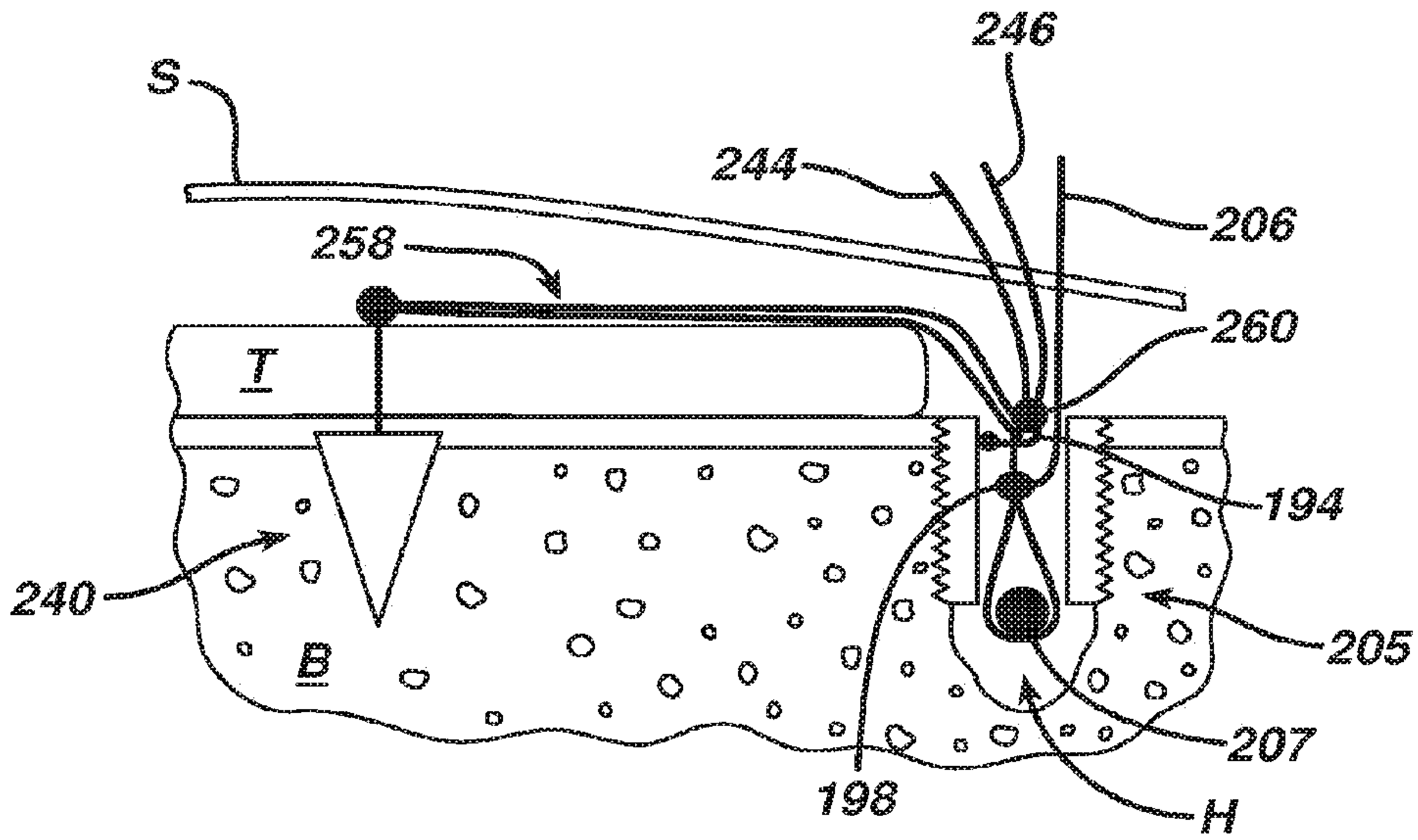
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FIG. 26

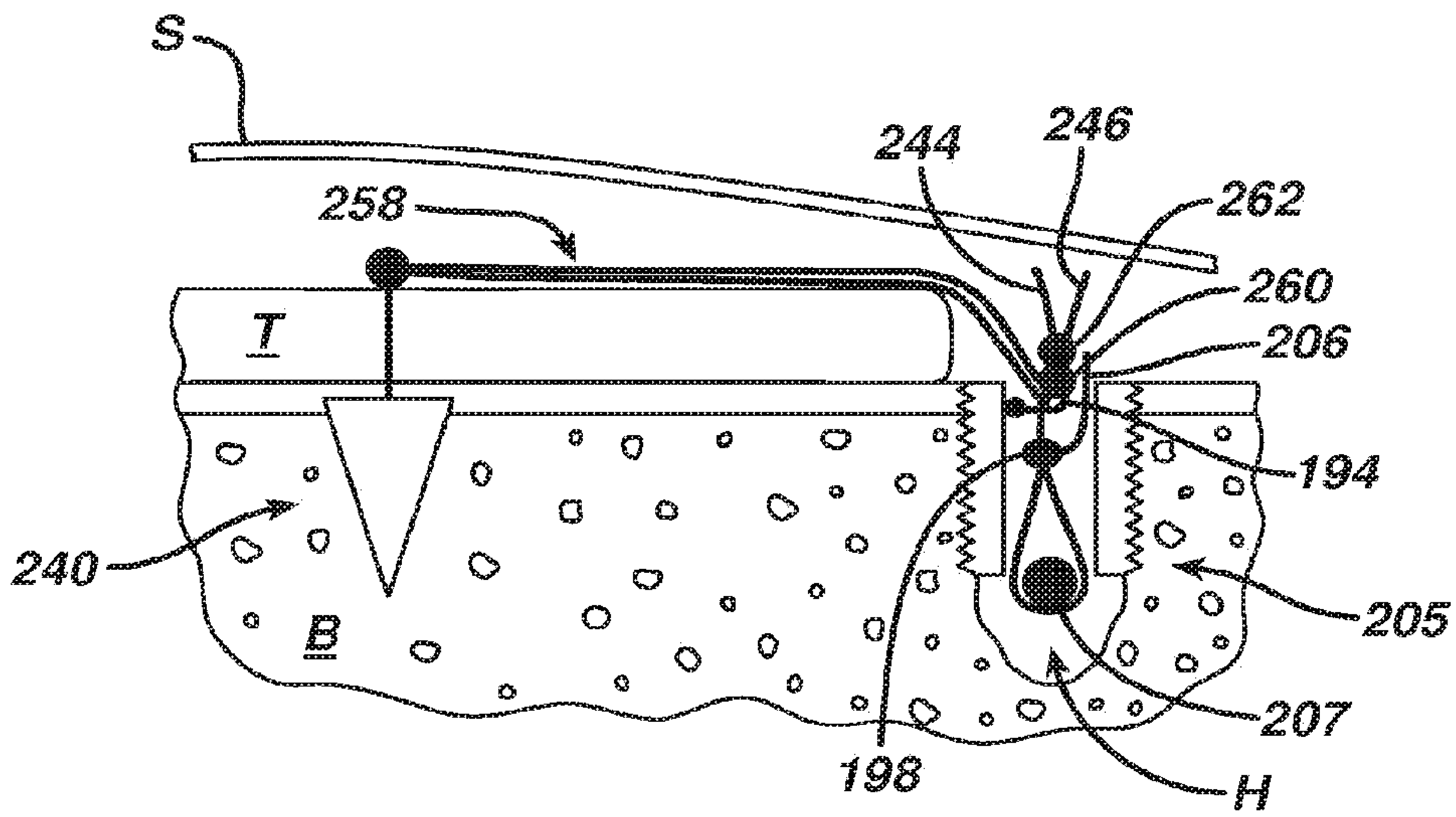
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FIG. 27

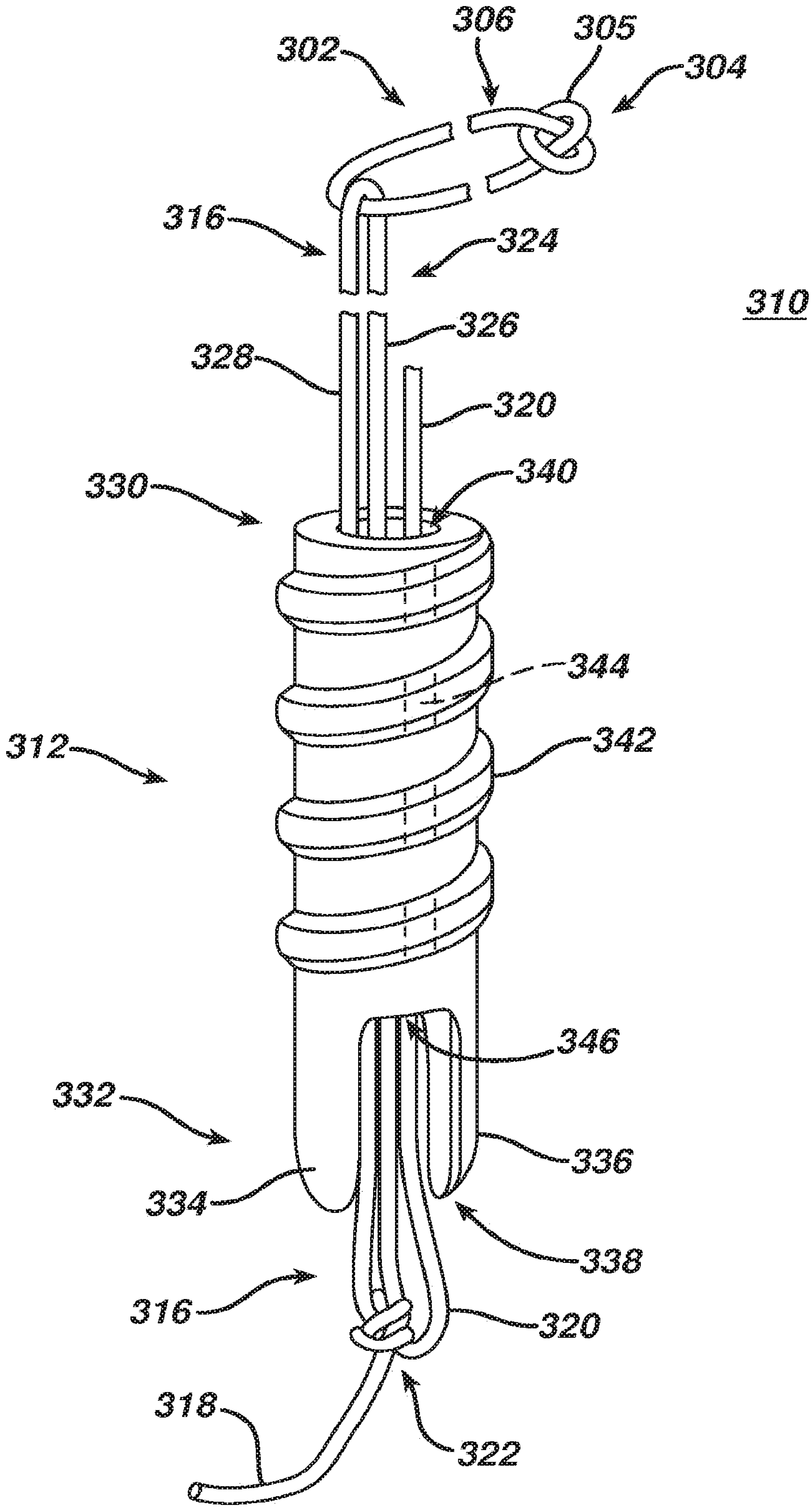
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FIG. 28

FIG. 29

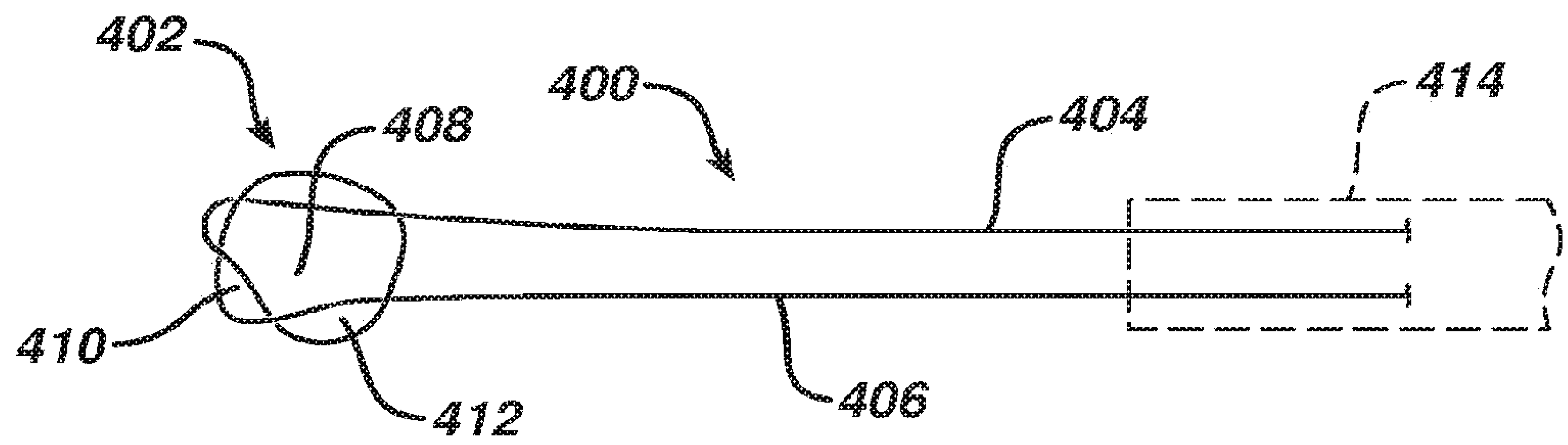


FIG. 30

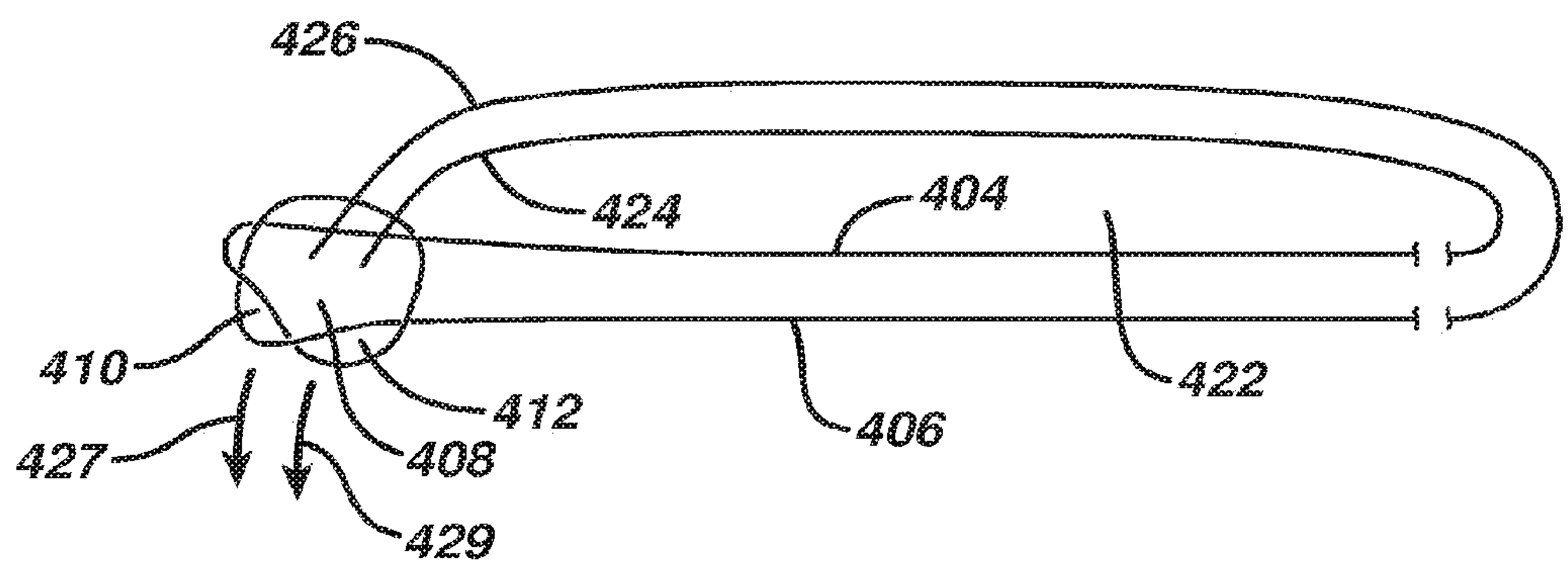
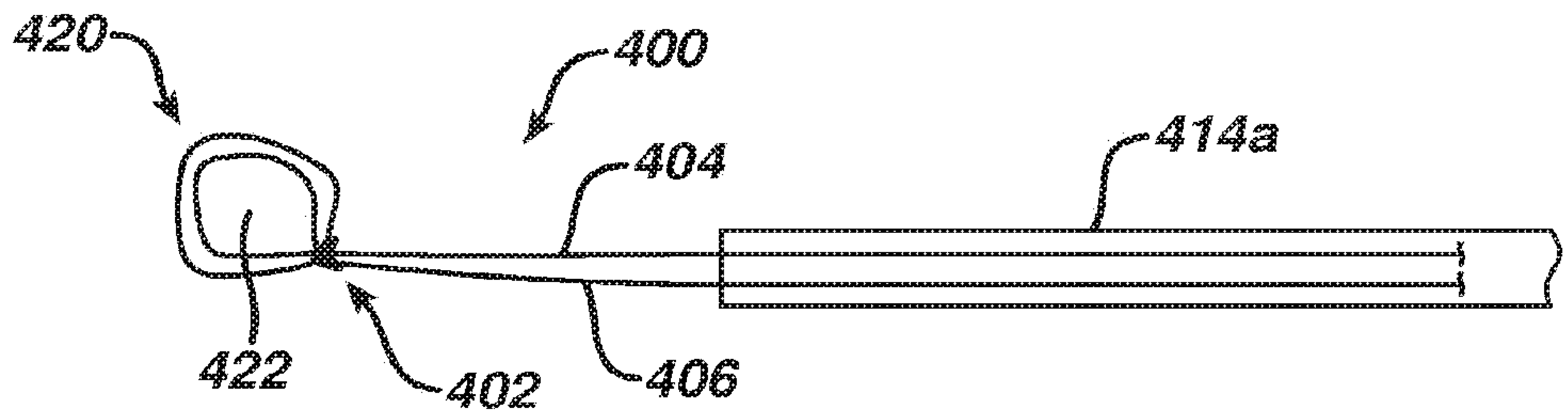


FIG. 31



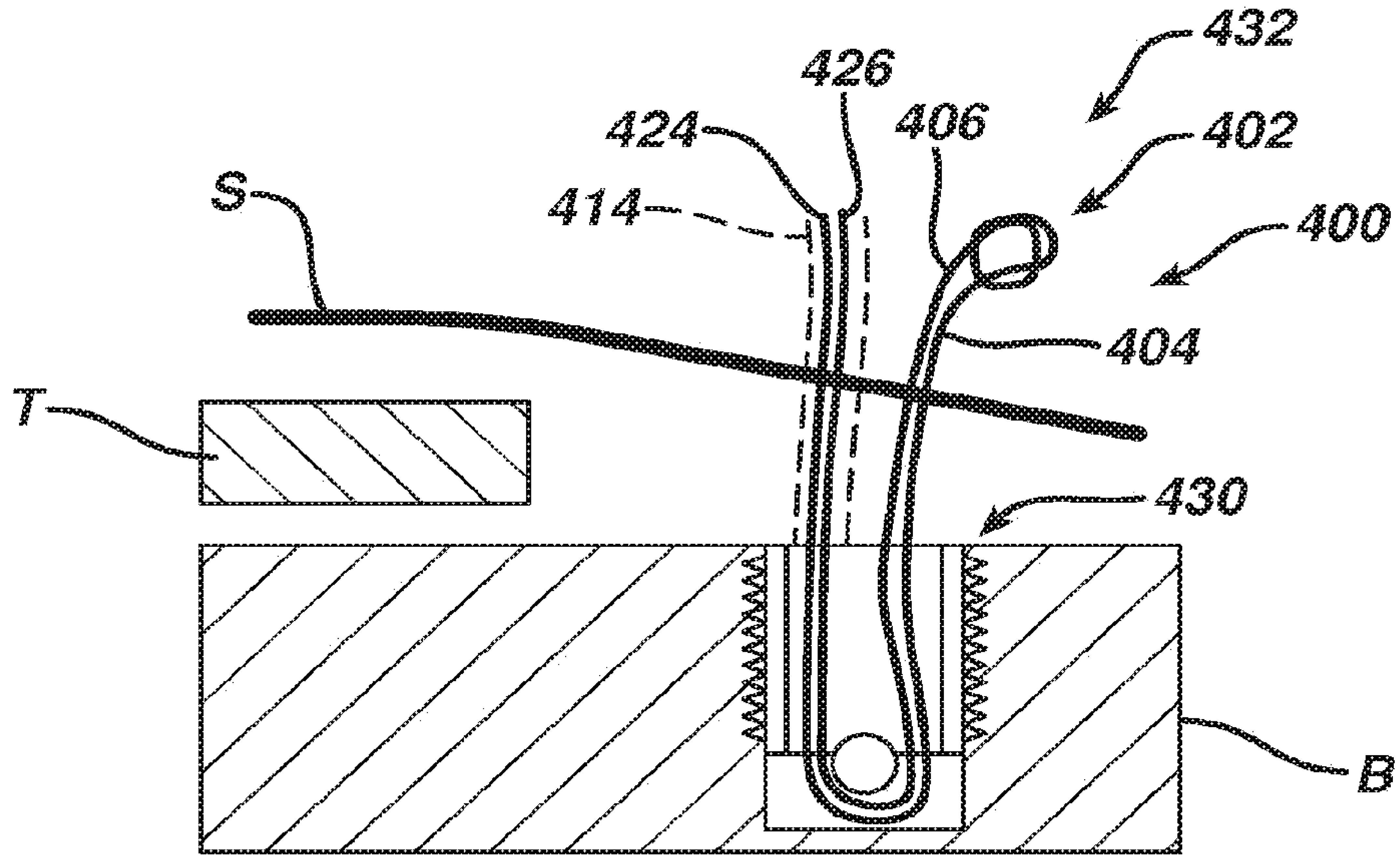

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FIG. 32

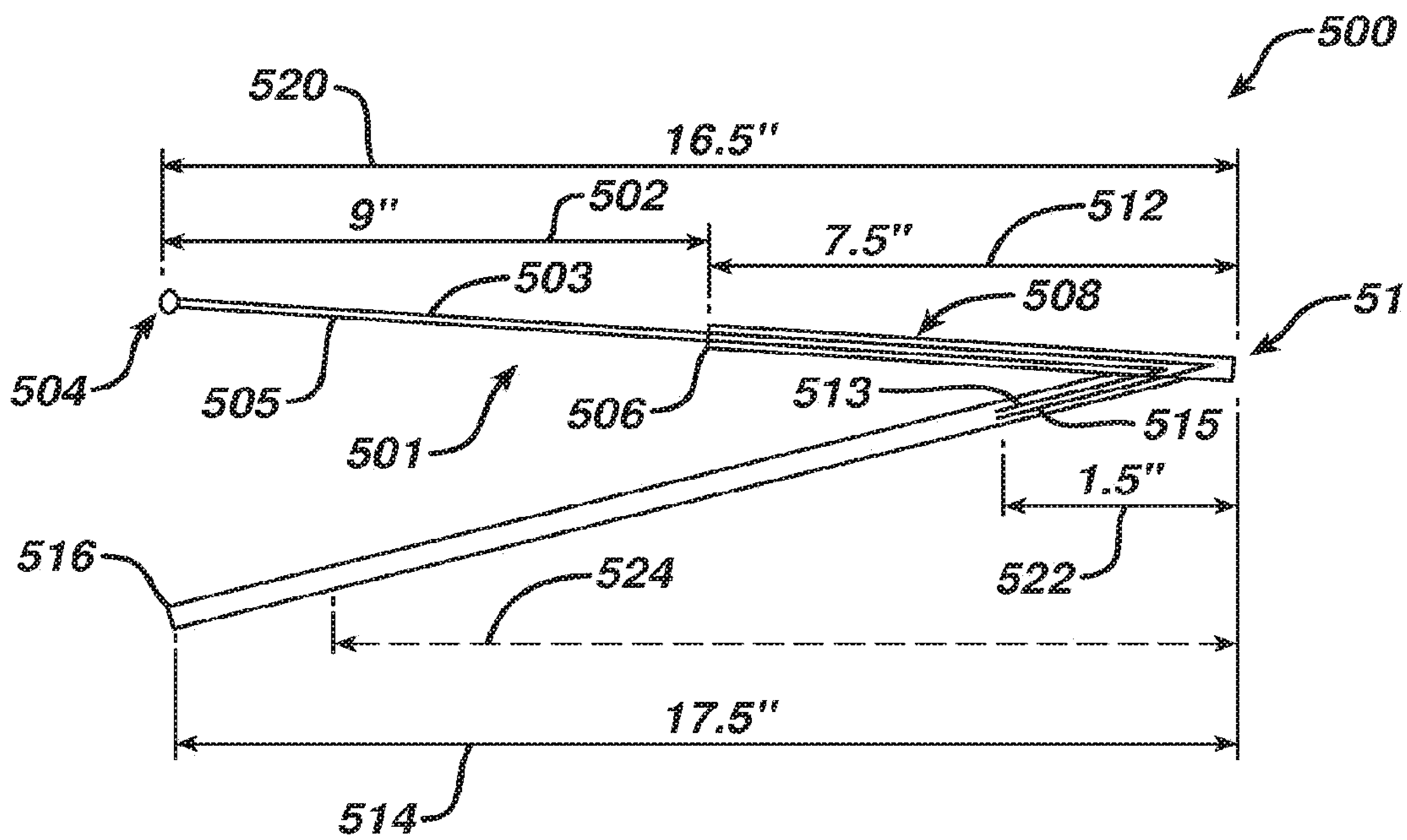
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FIG. 33

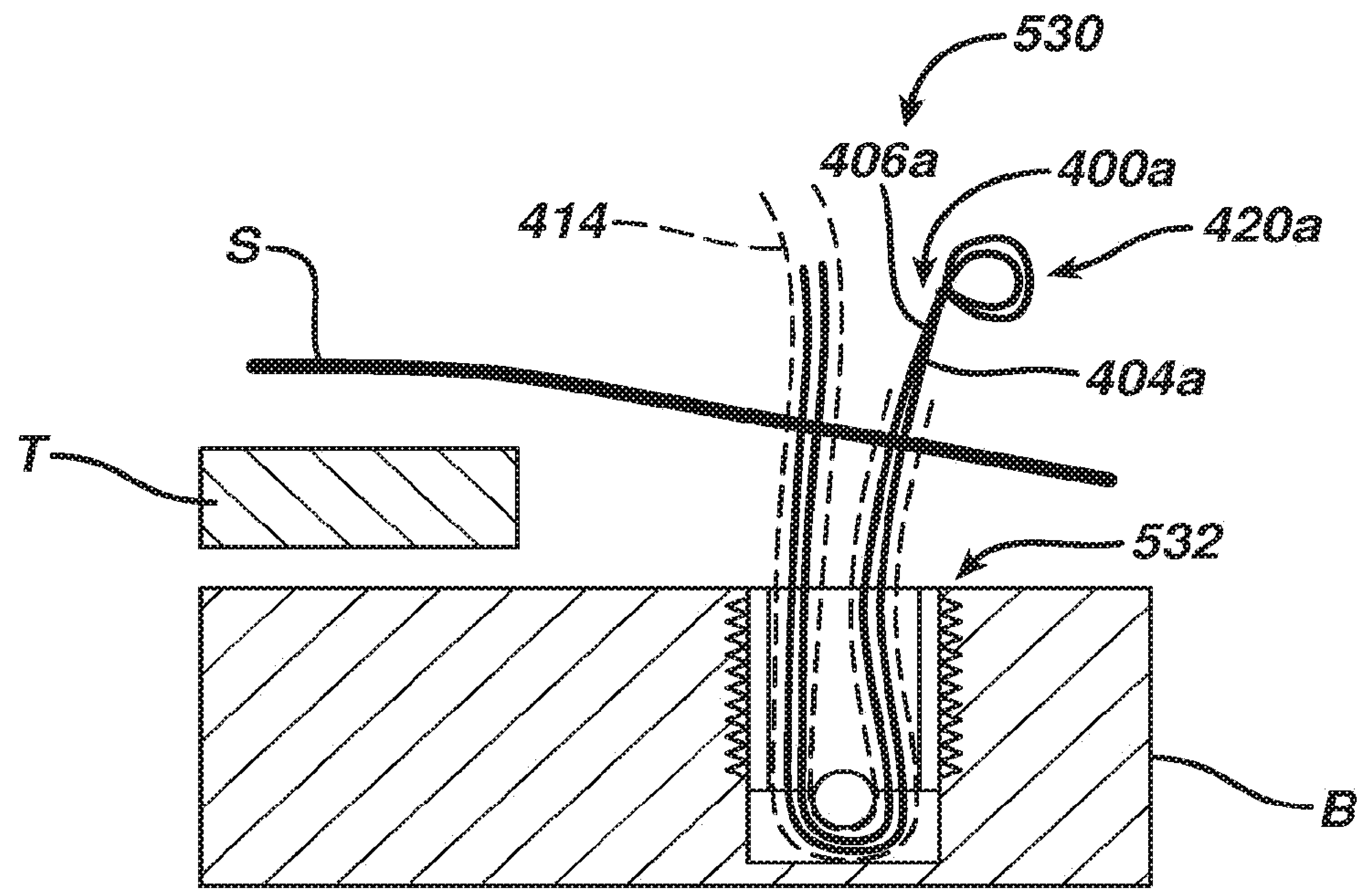
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FIG. 34

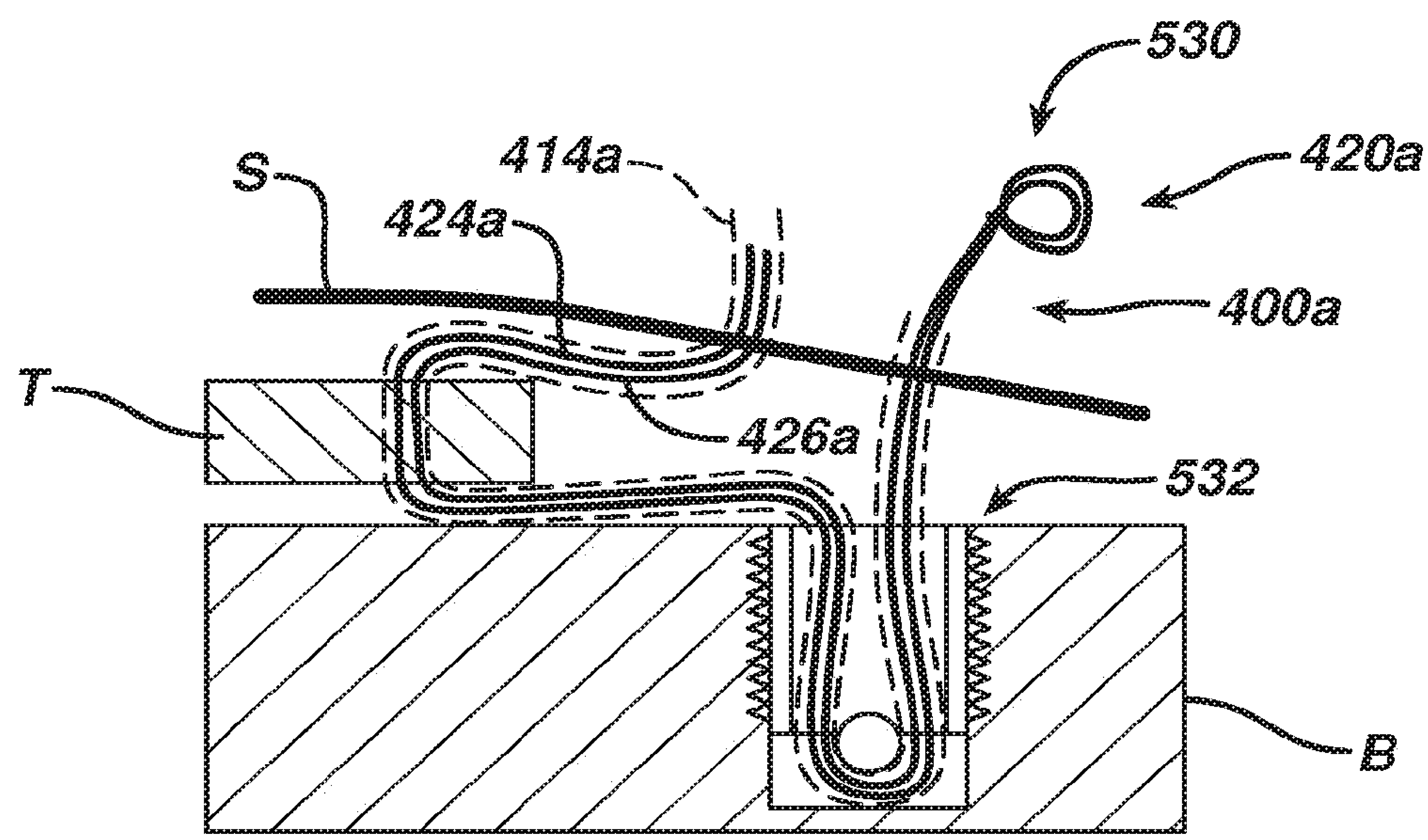
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FIG. 35

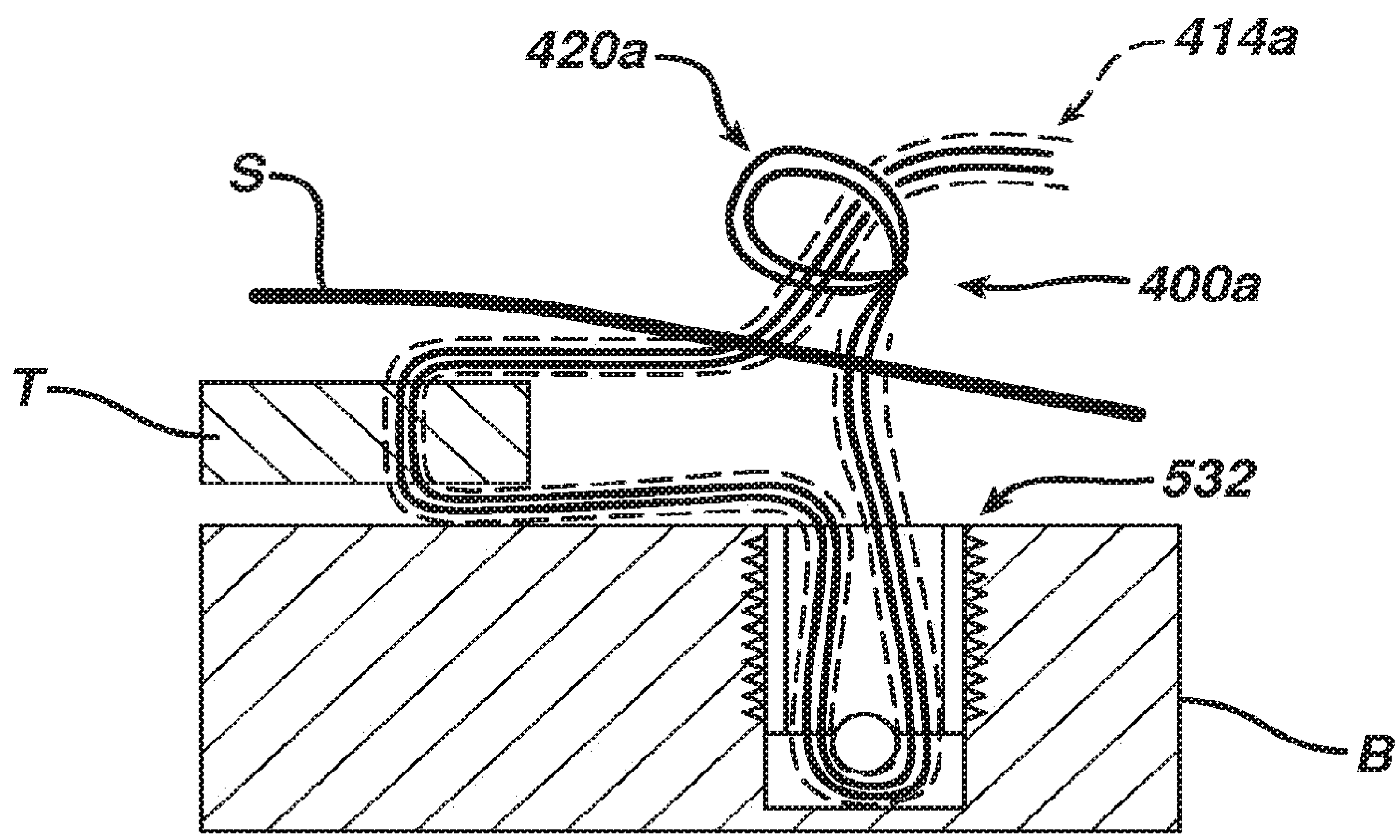


FIG. 36

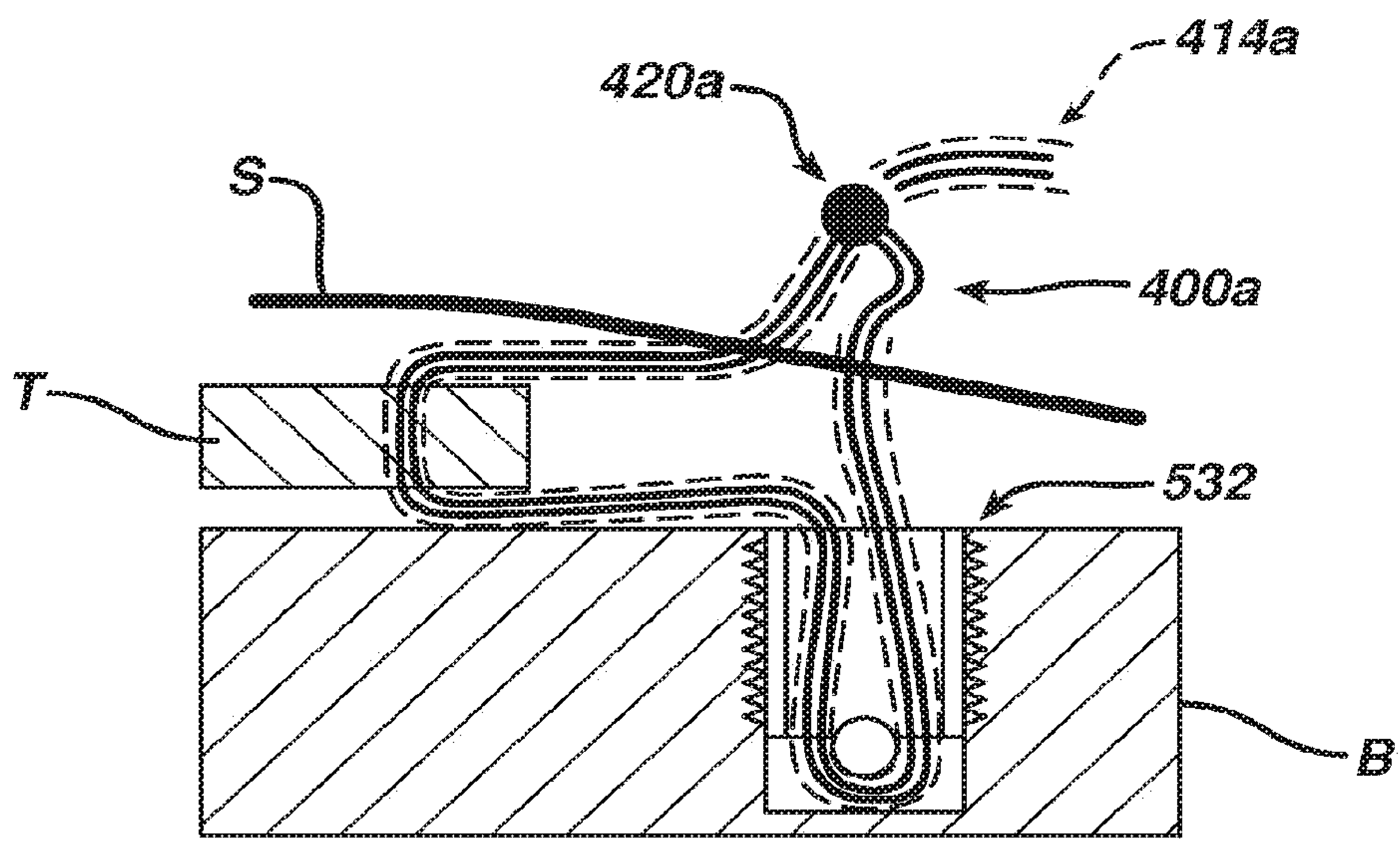


FIG. 37

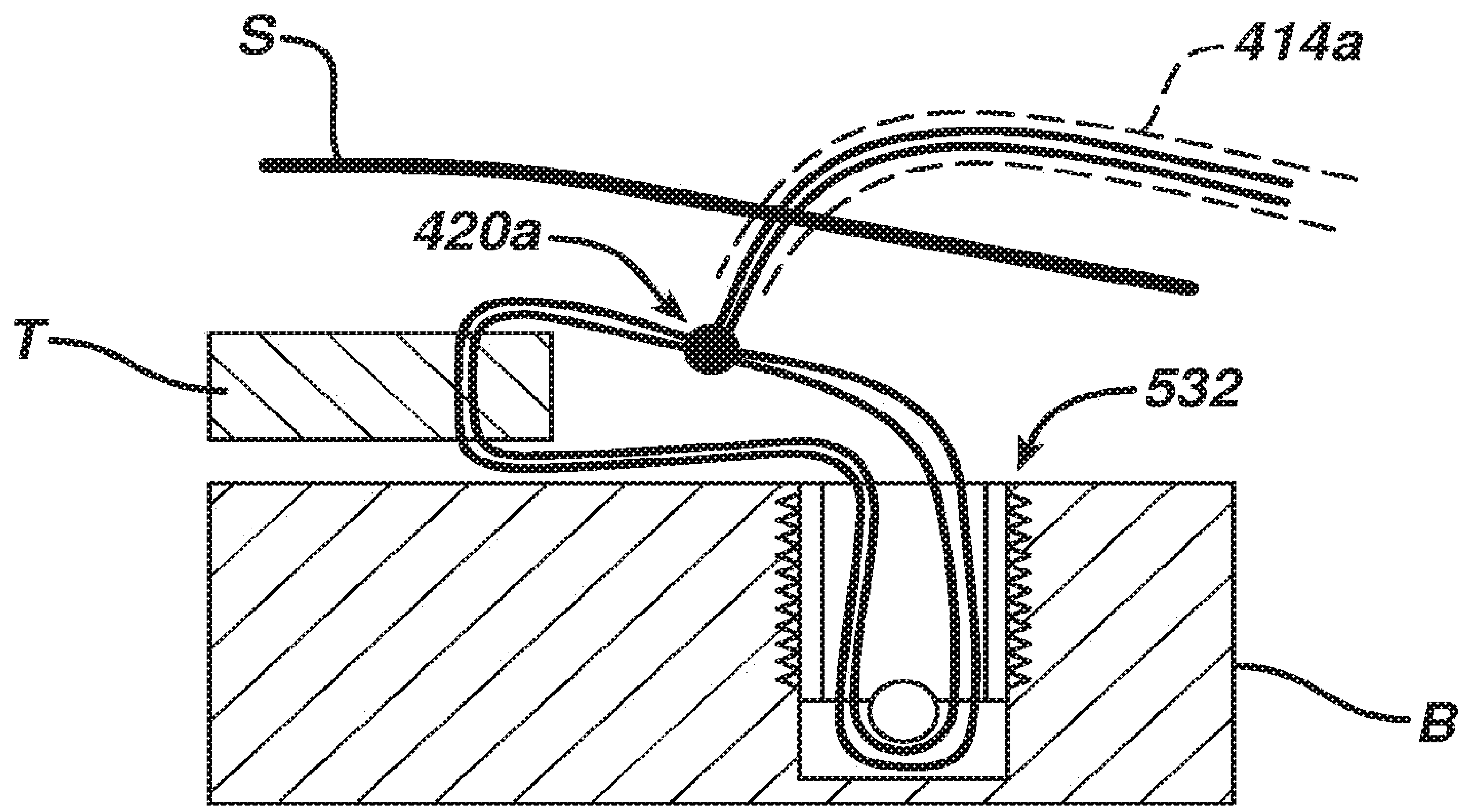


FIG. 38

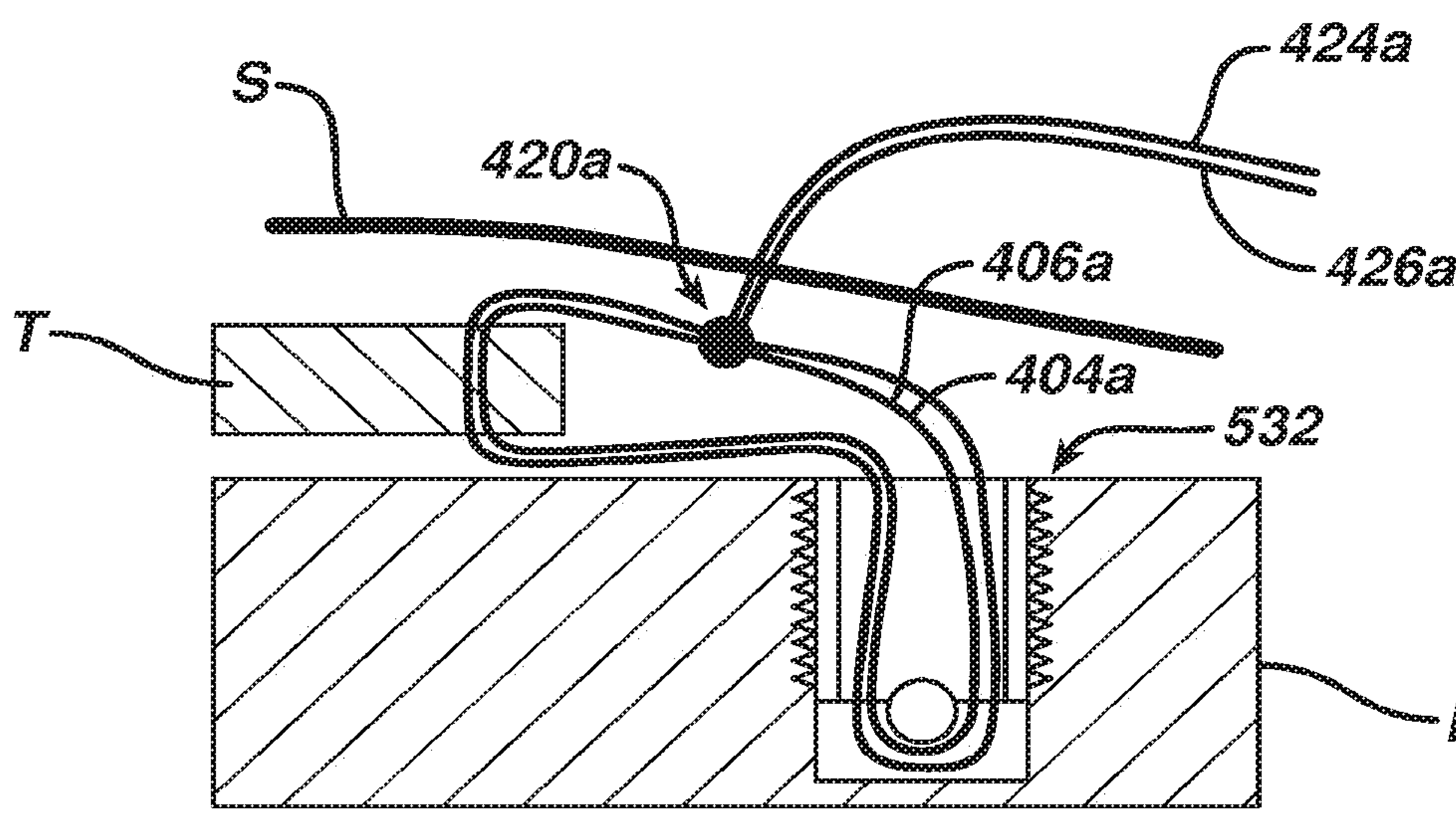


FIG. 39

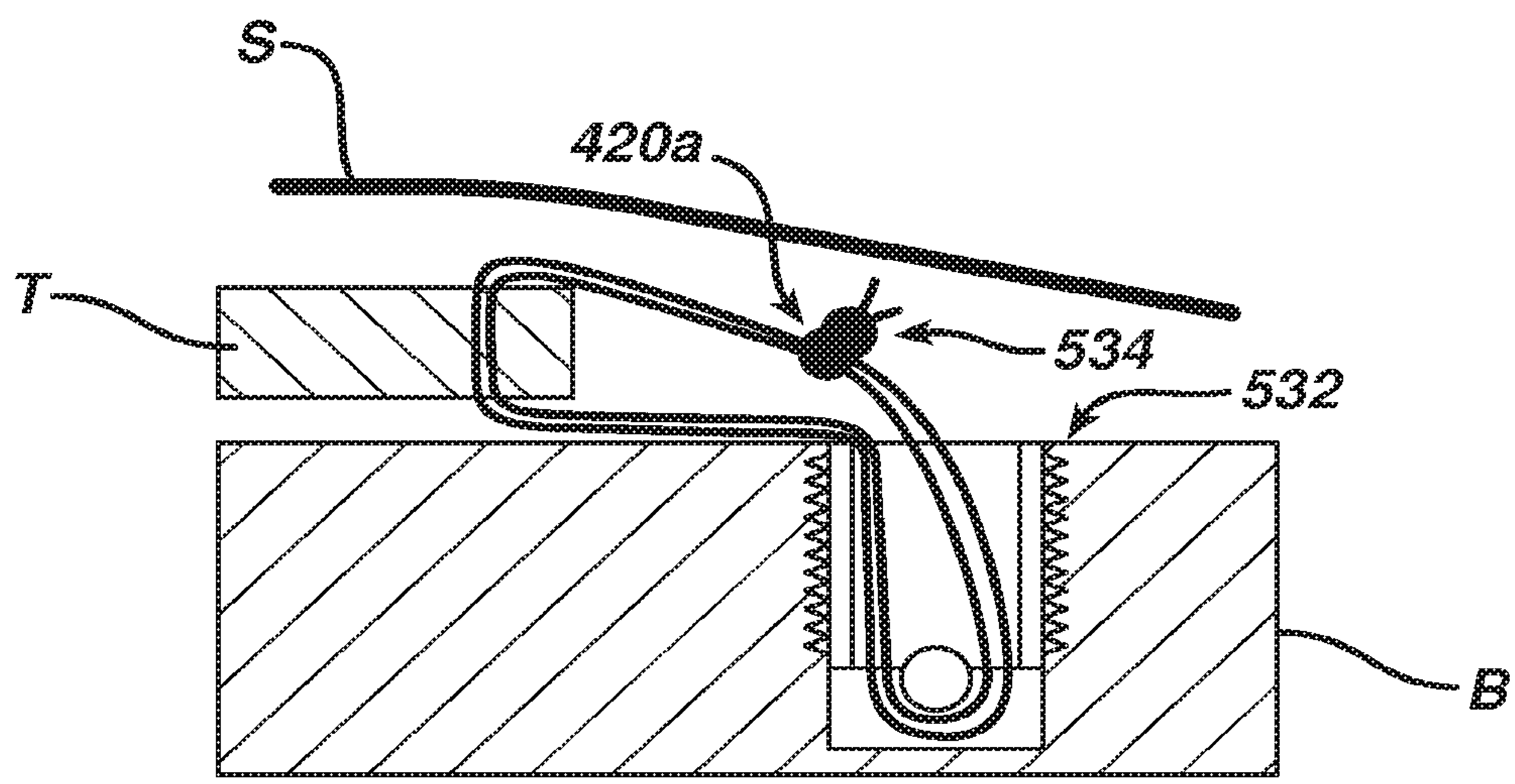
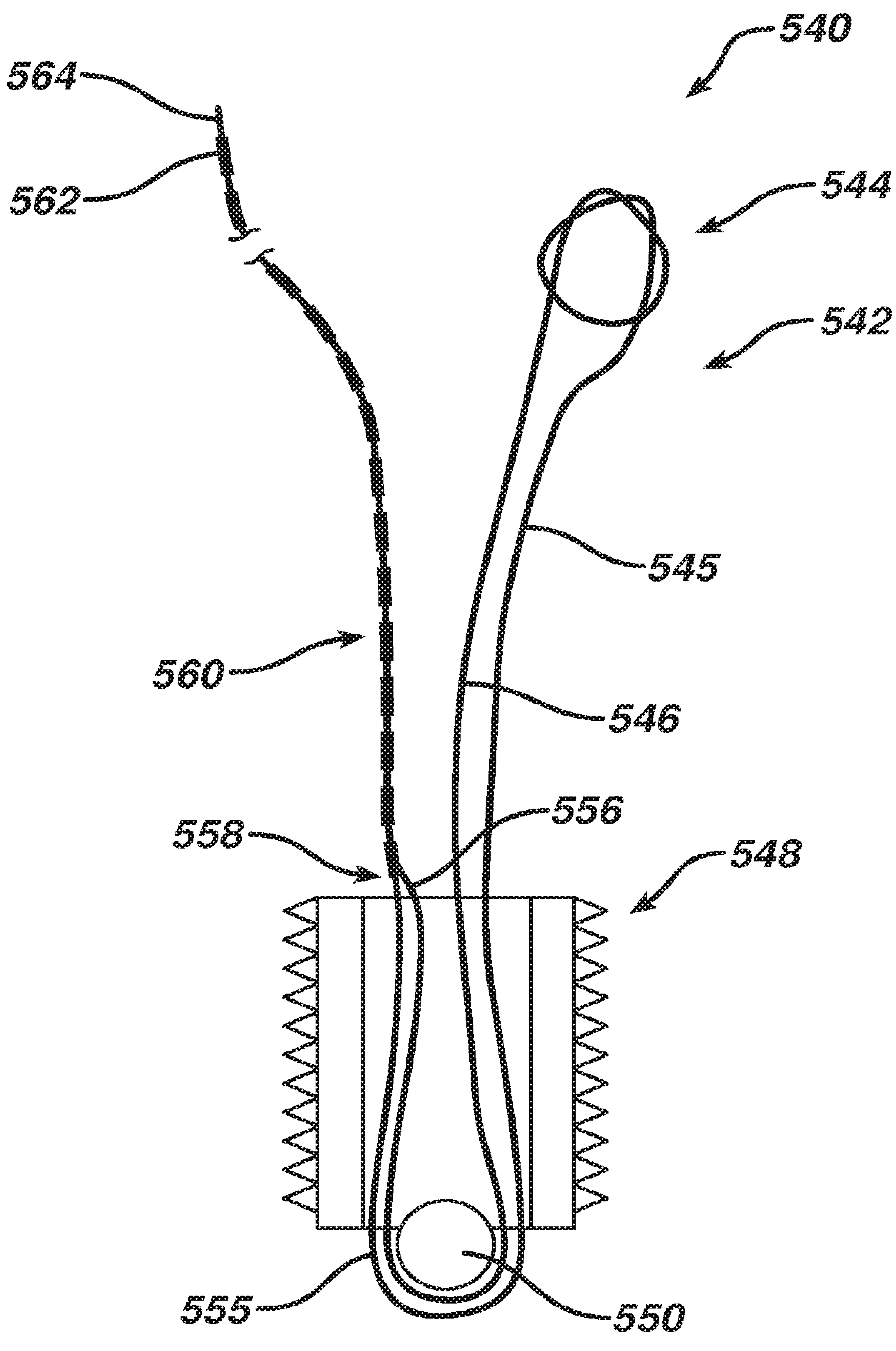


FIG. 40

FIG. 41



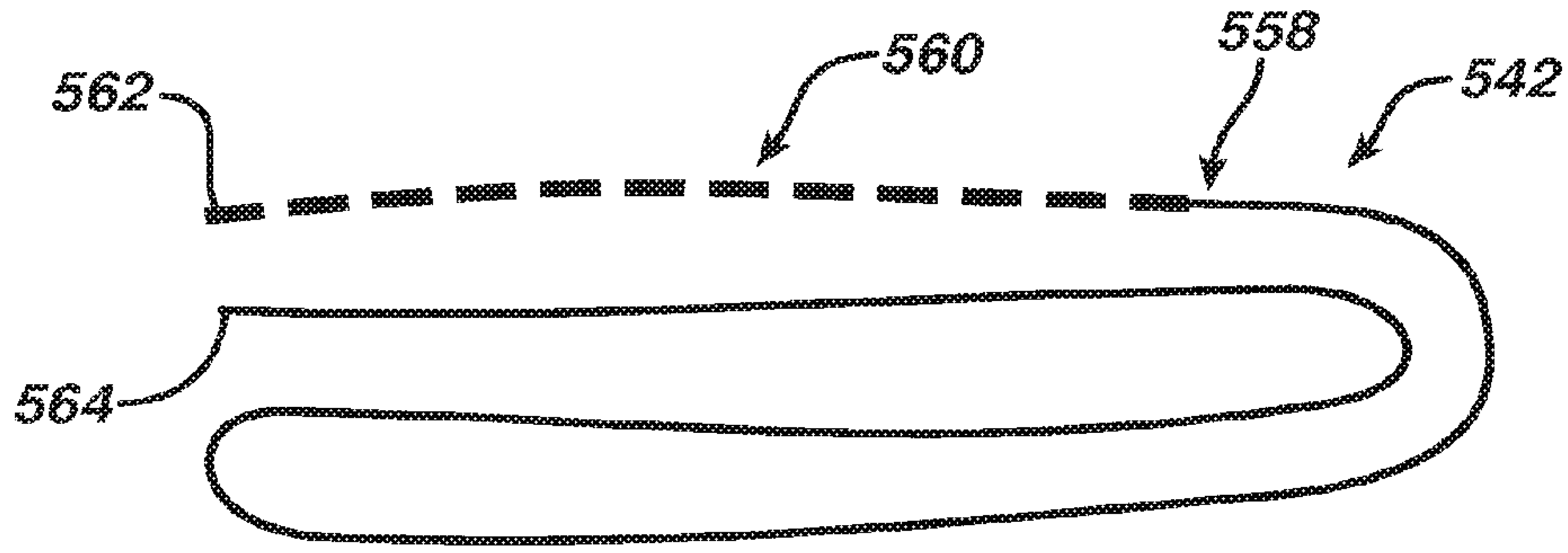


FIG. 42A

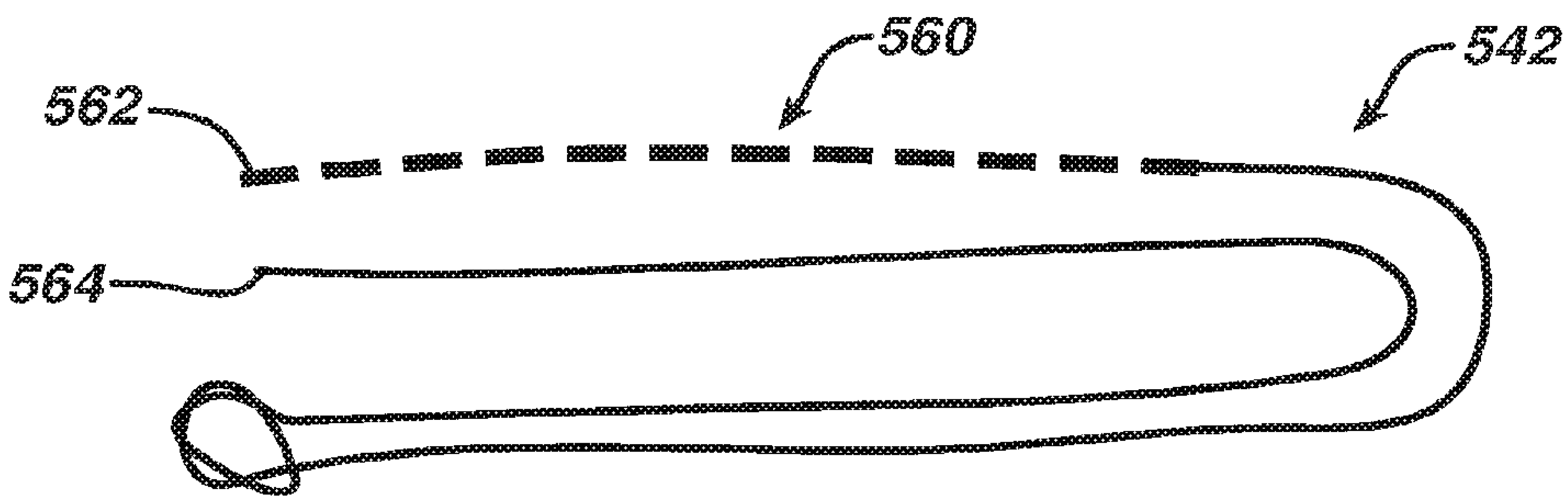


FIG. 42B

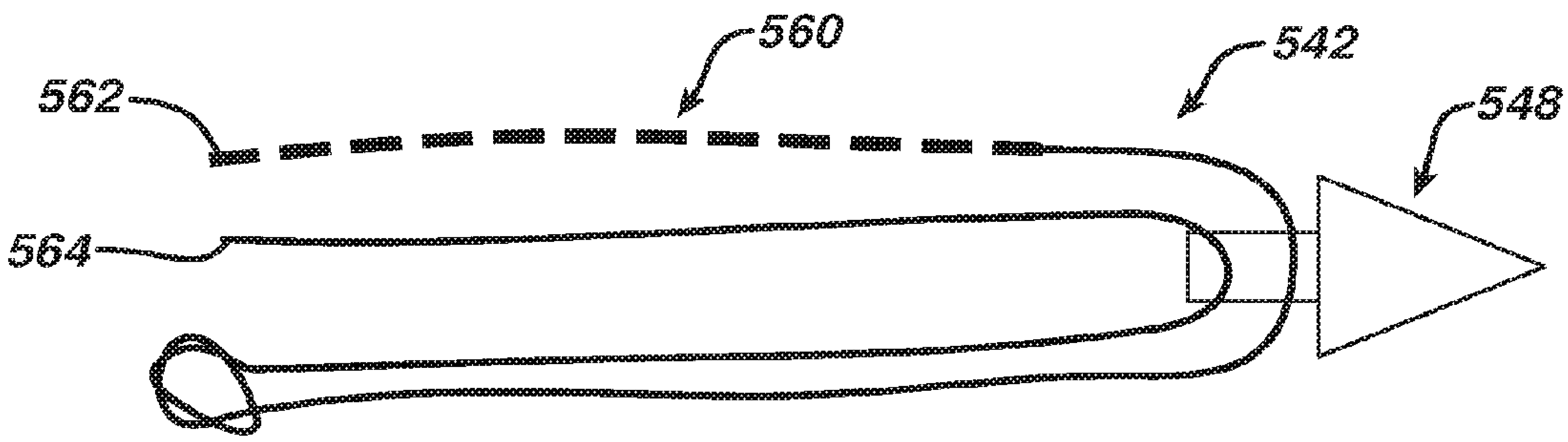


FIG. 42C

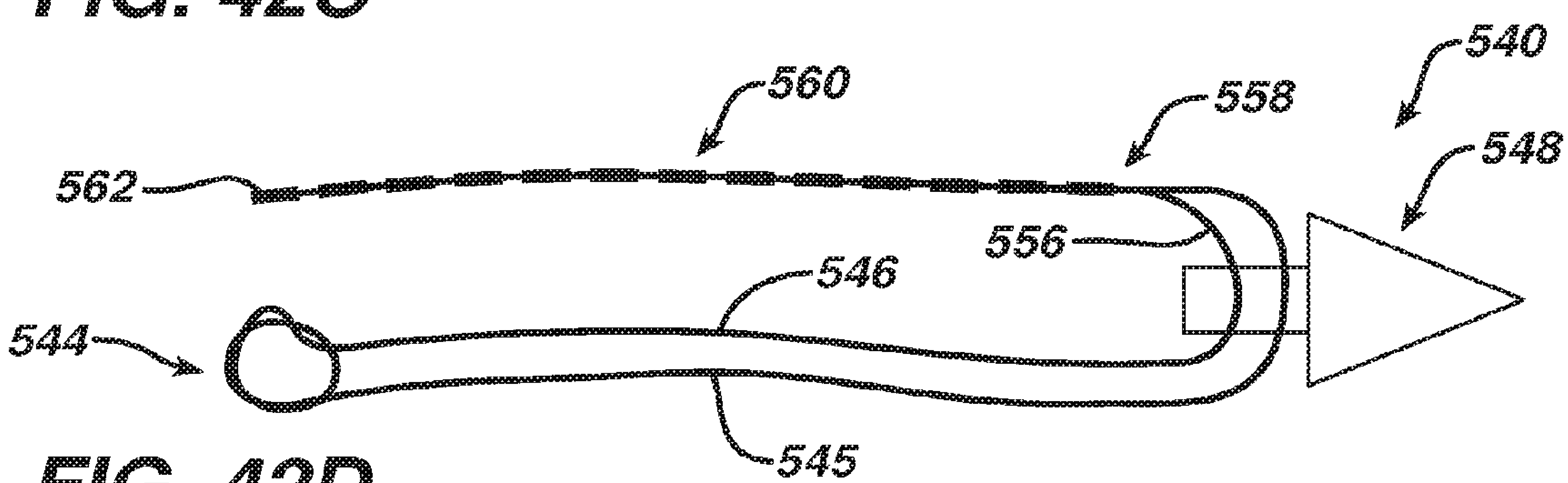


FIG. 42D

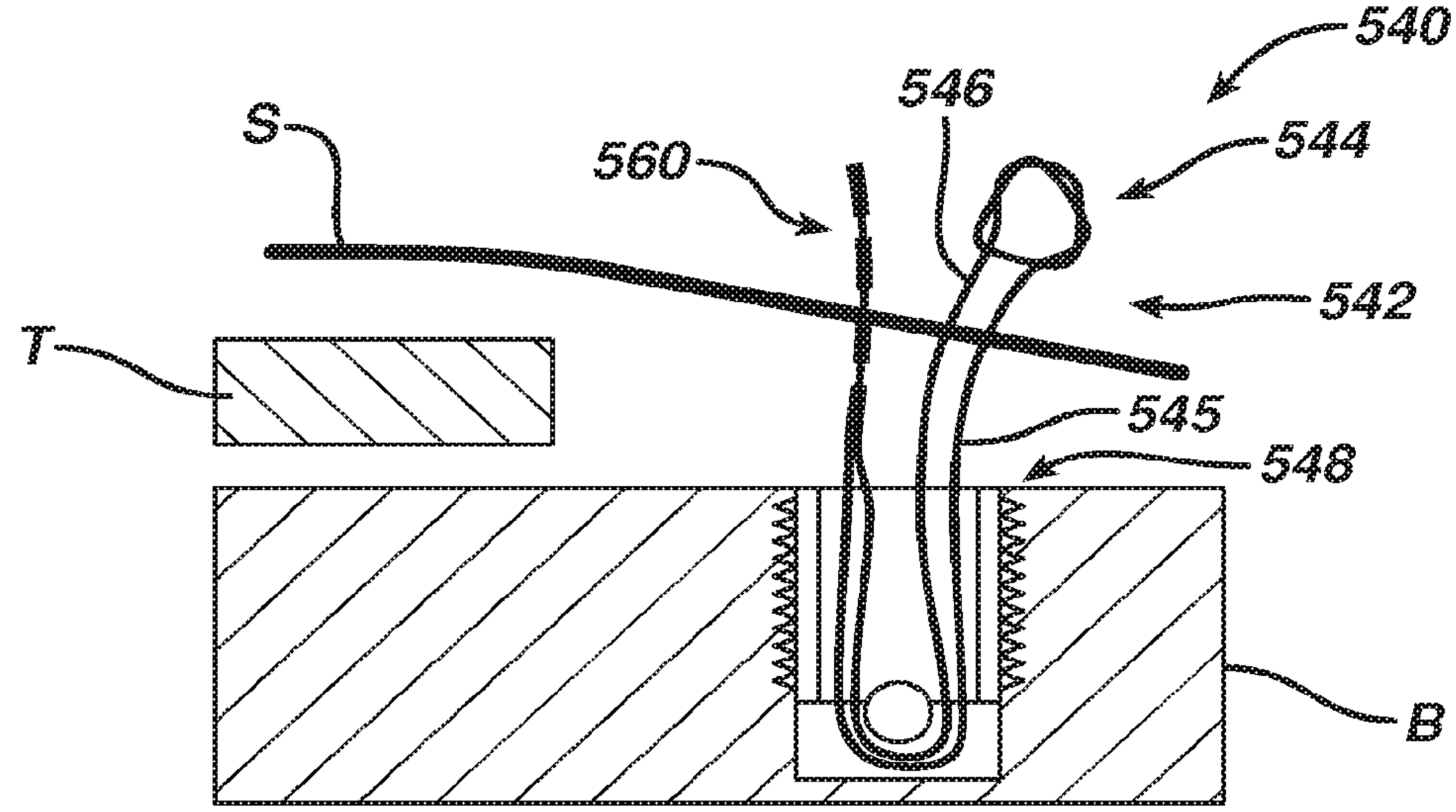


FIG. 43

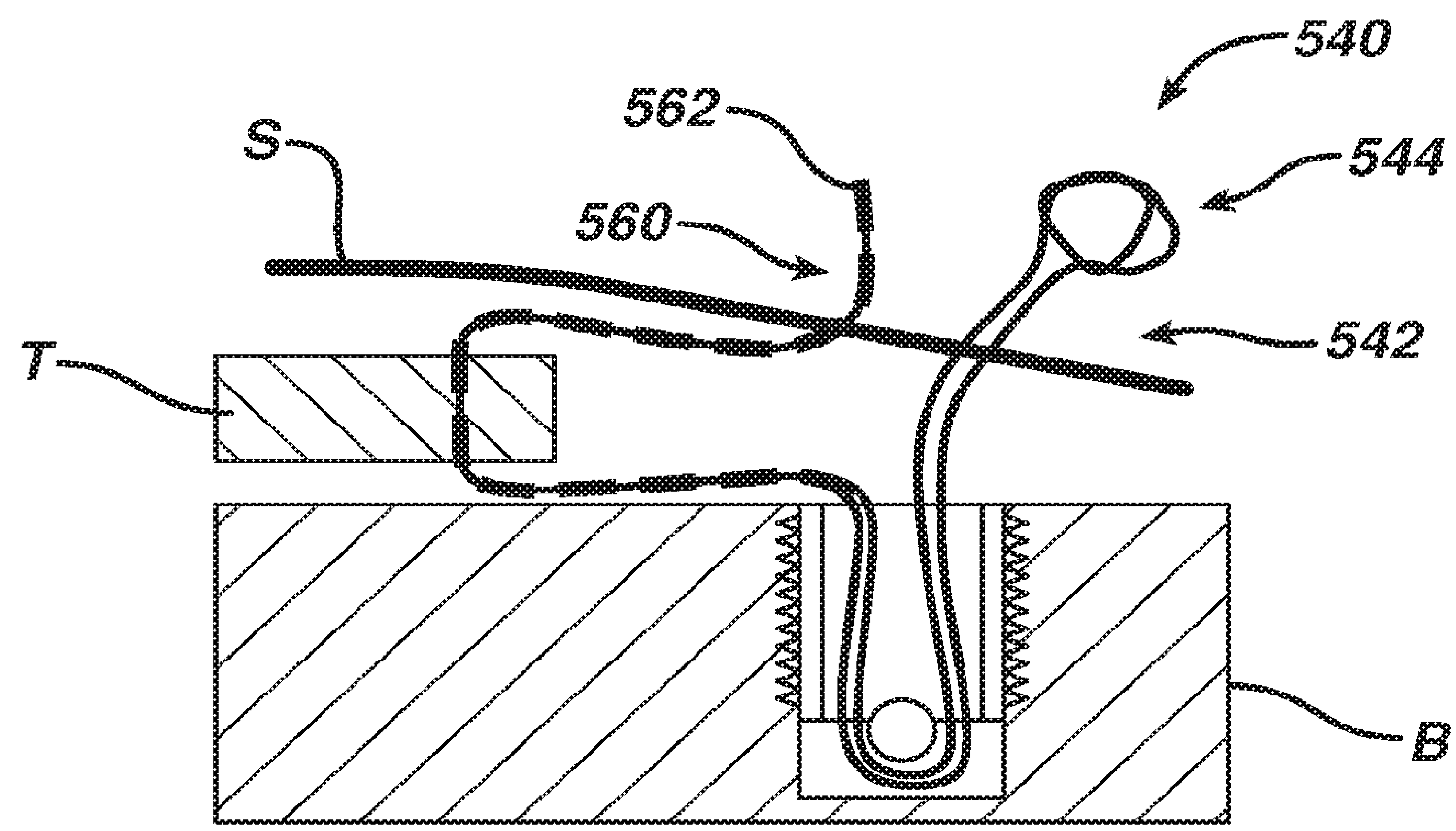


FIG. 44

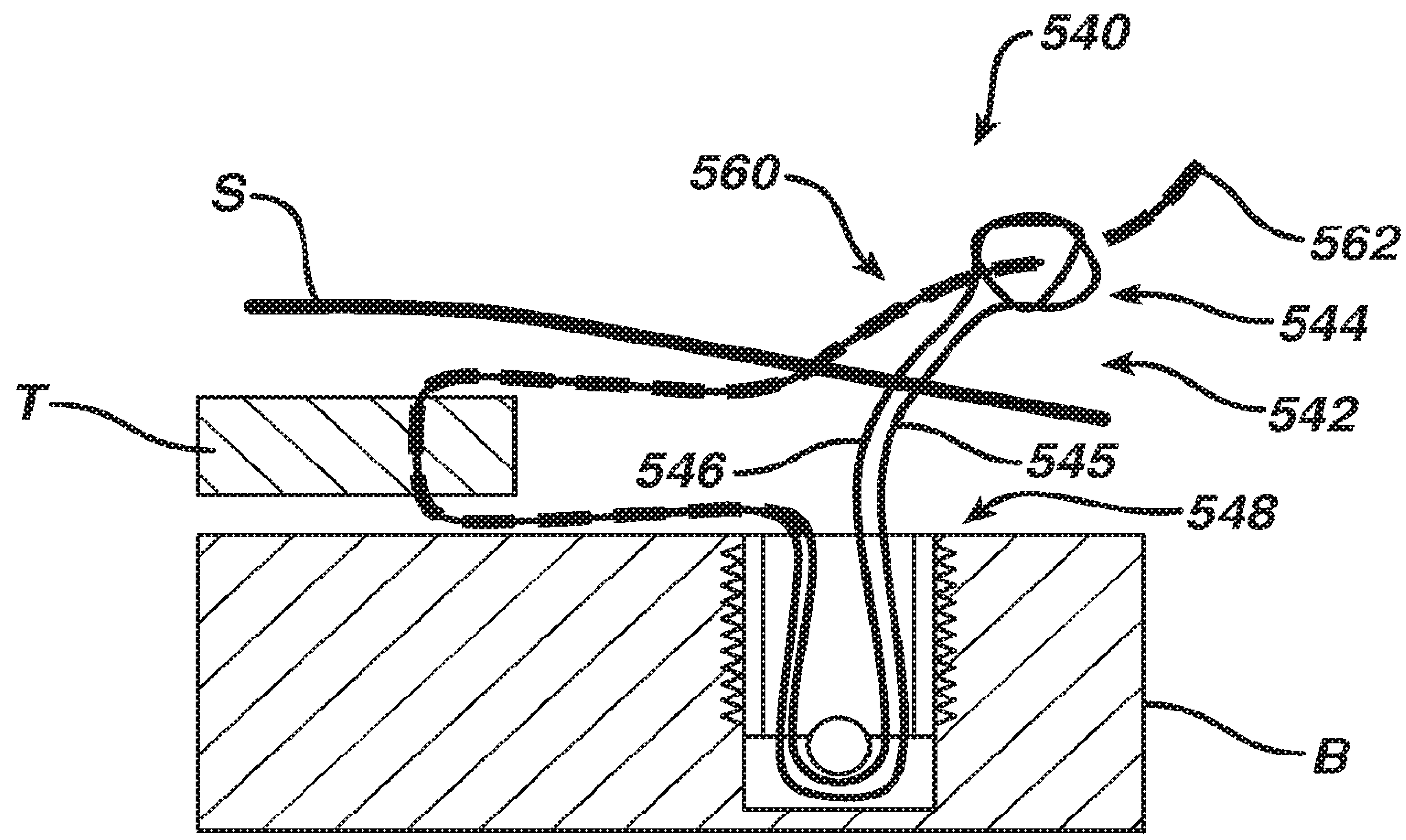

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FIG. 45

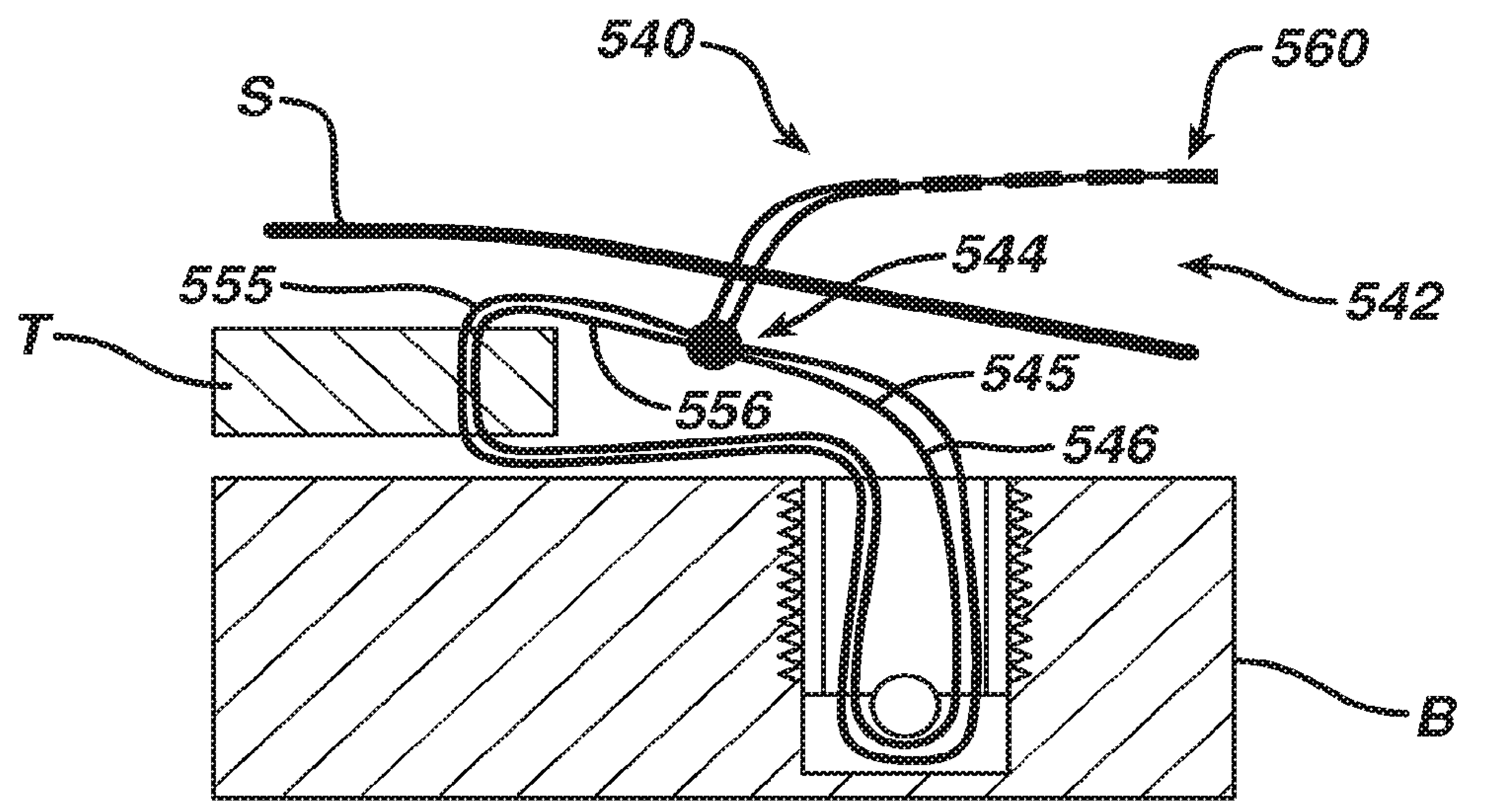
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FIG. 46

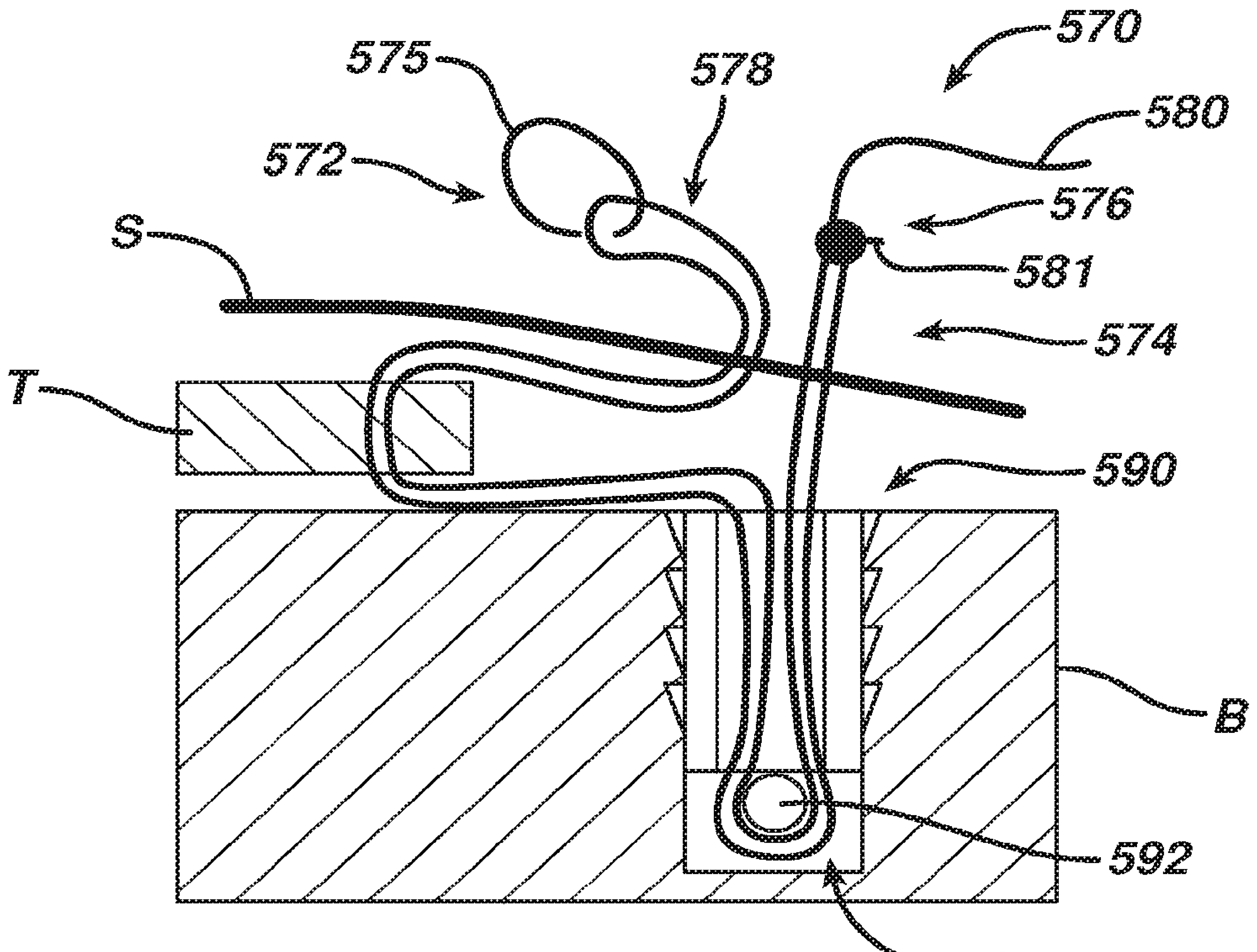
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FIG. 47

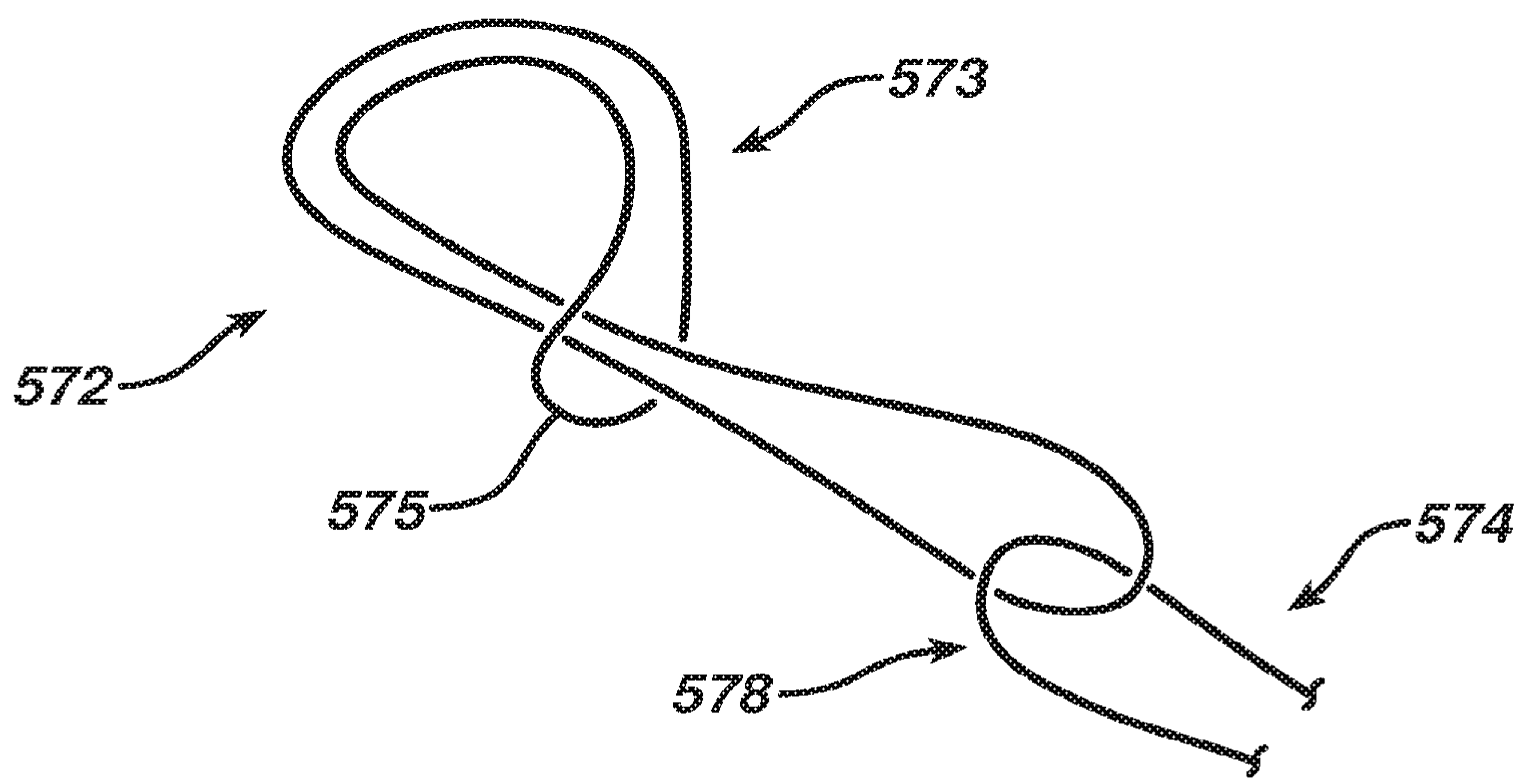
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FIG. 48

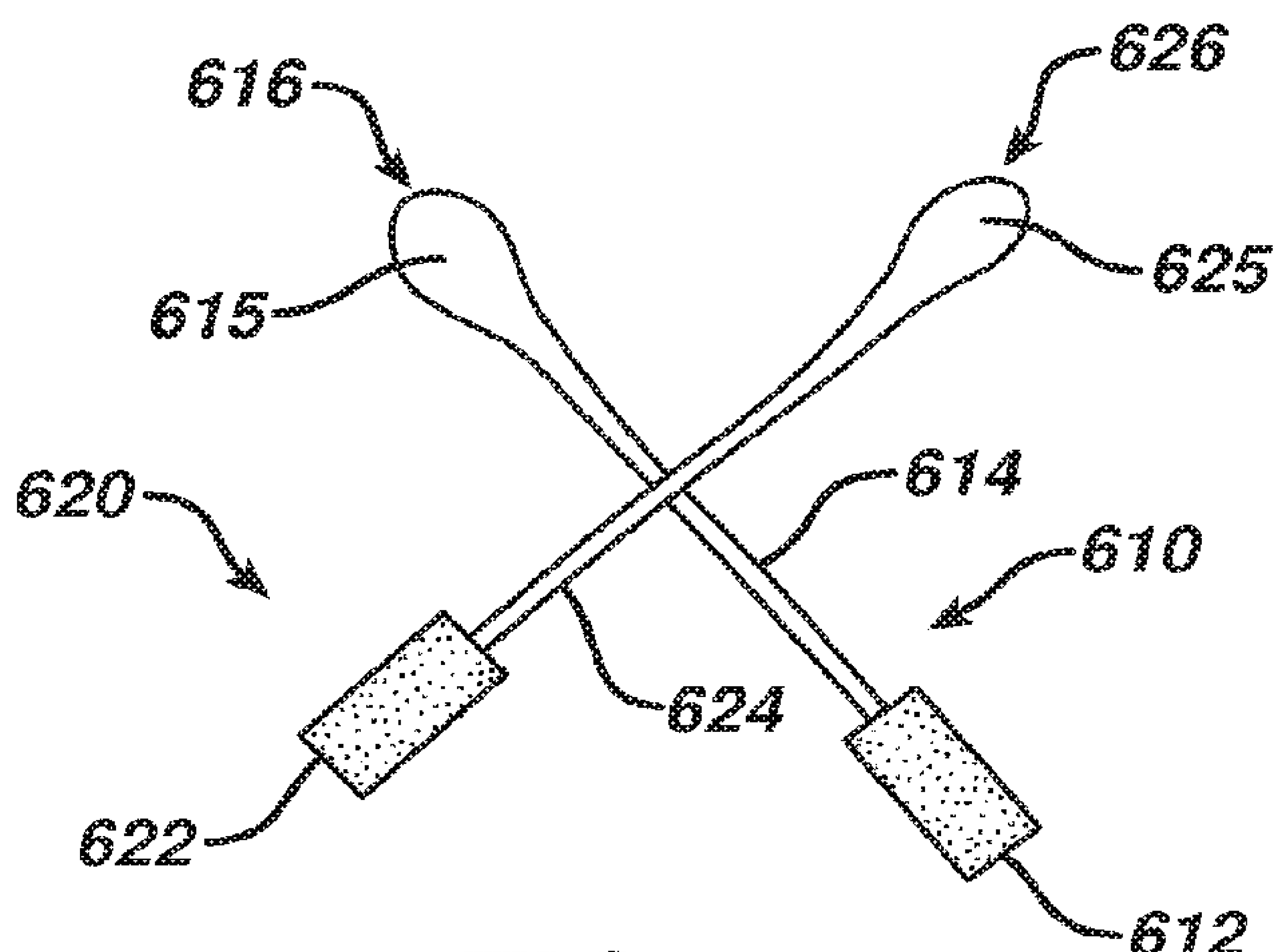

FIG. 51

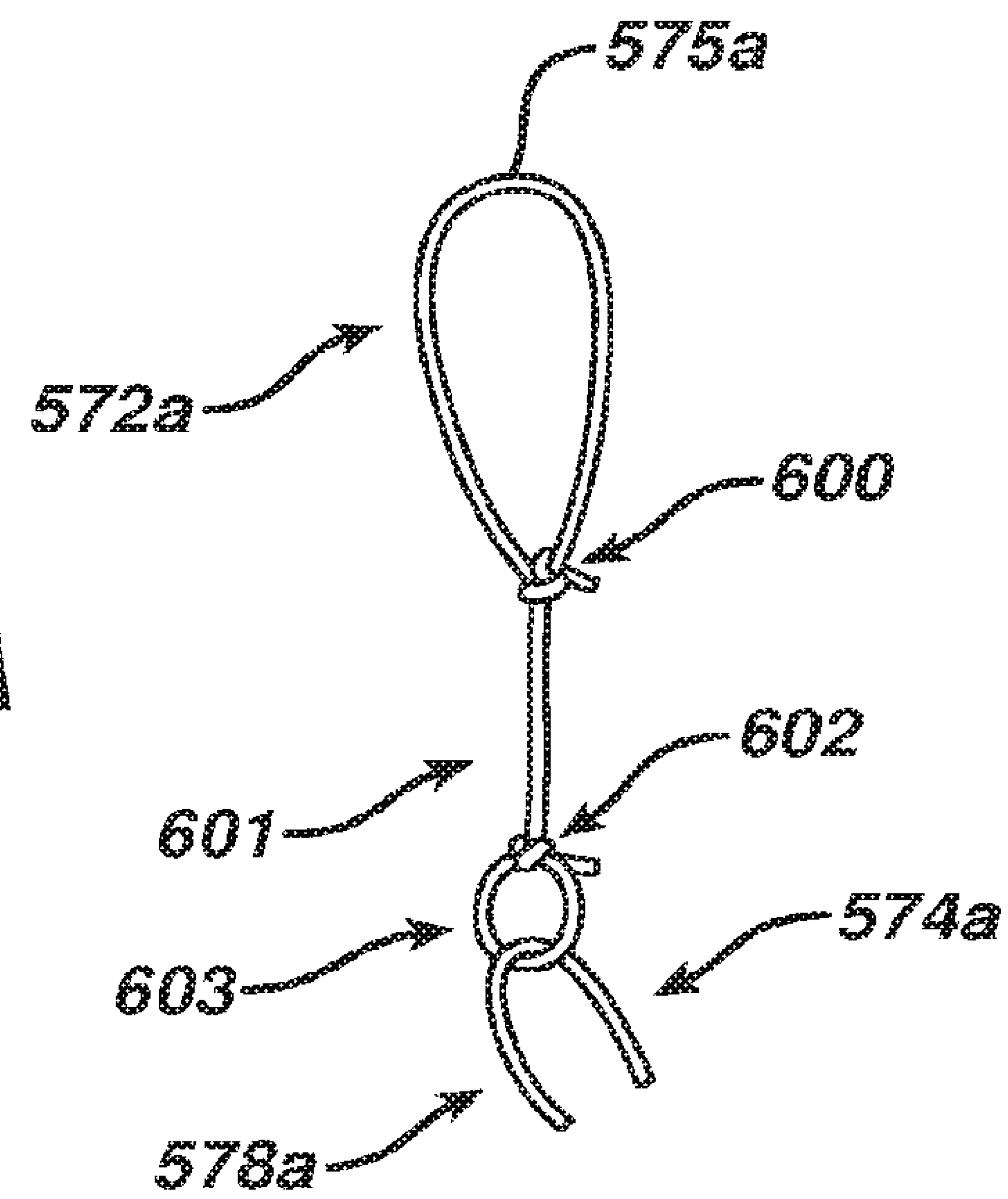

FIG. 48A

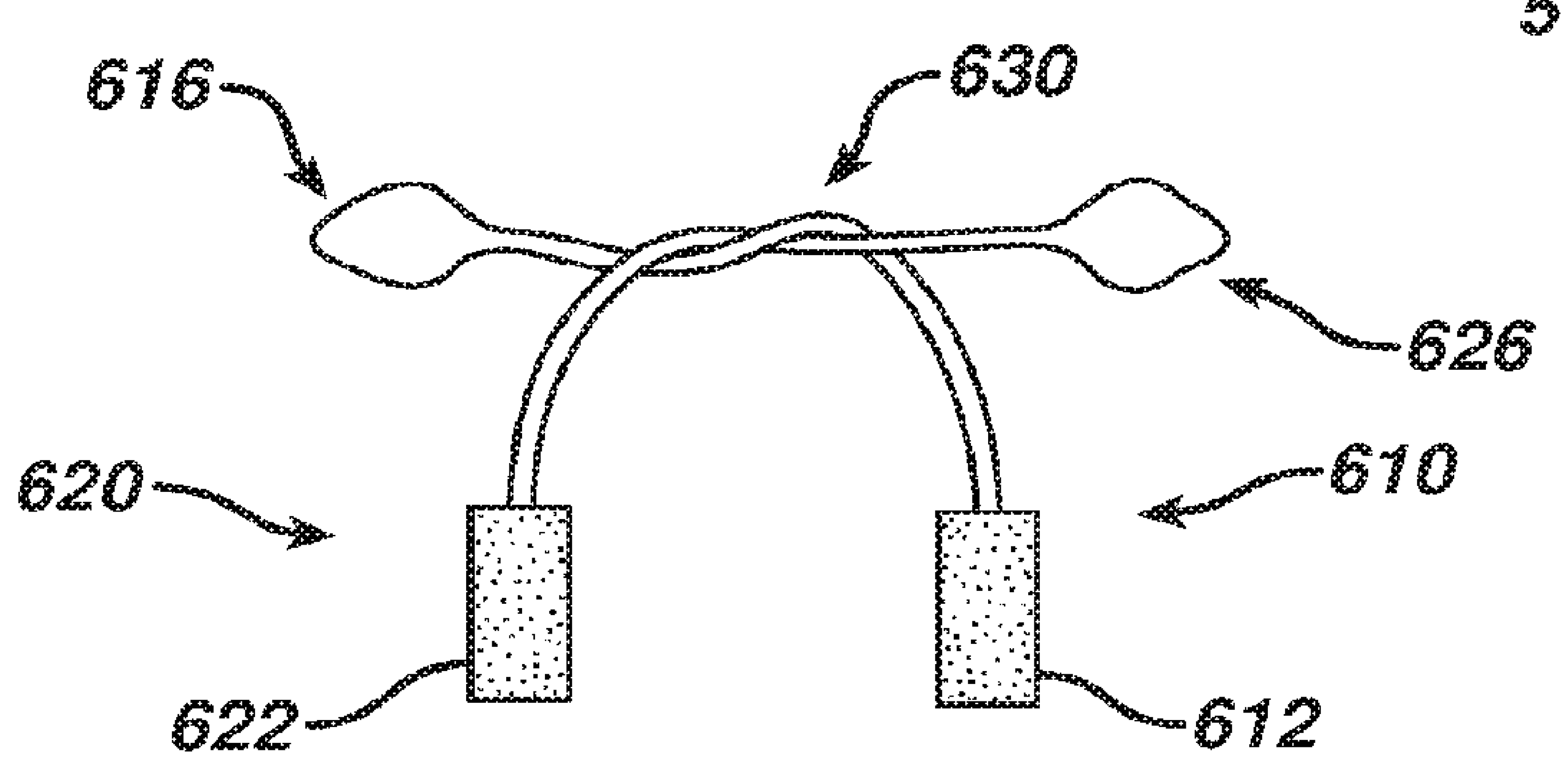

FIG. 52

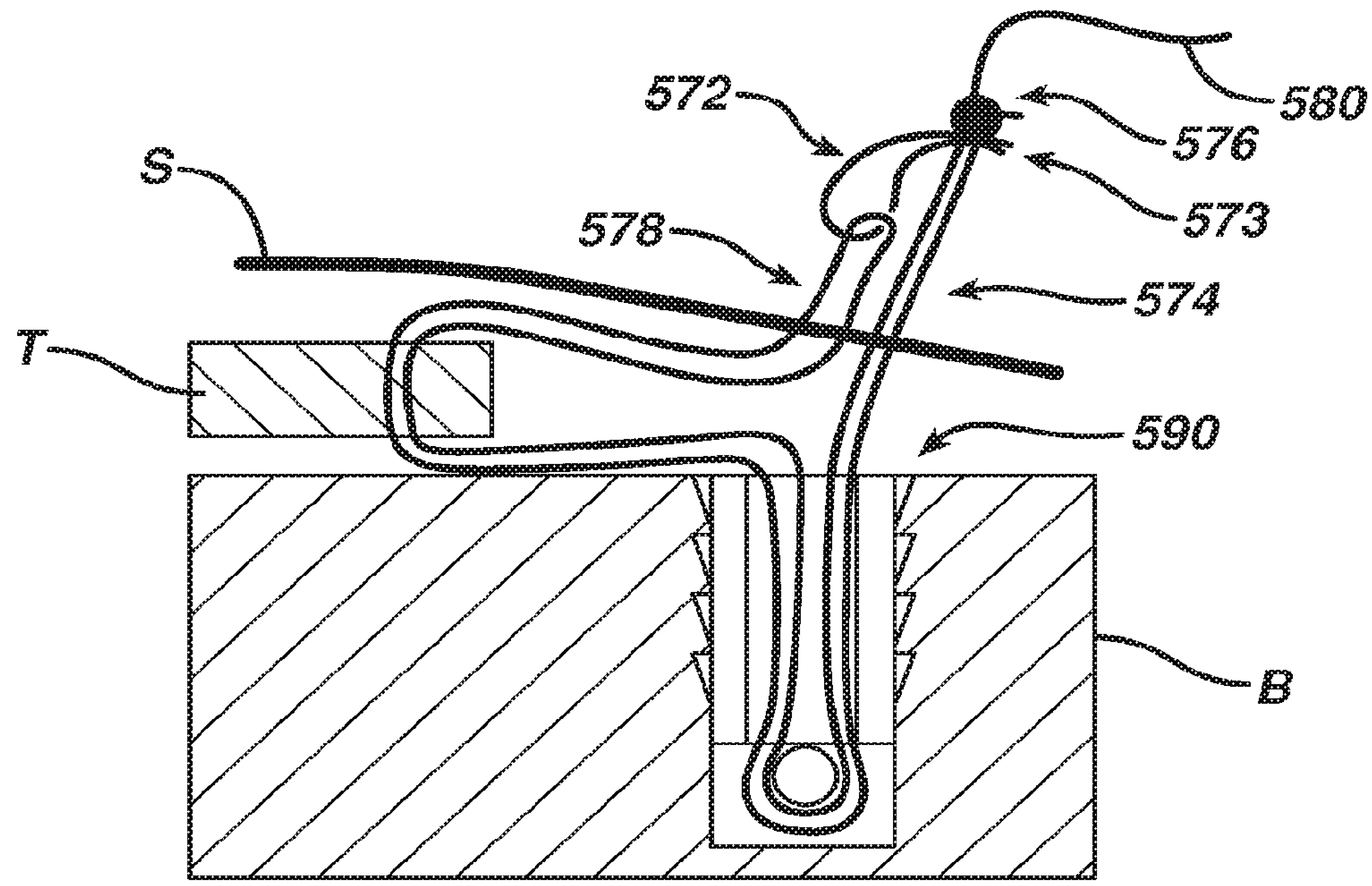

FIG. 49

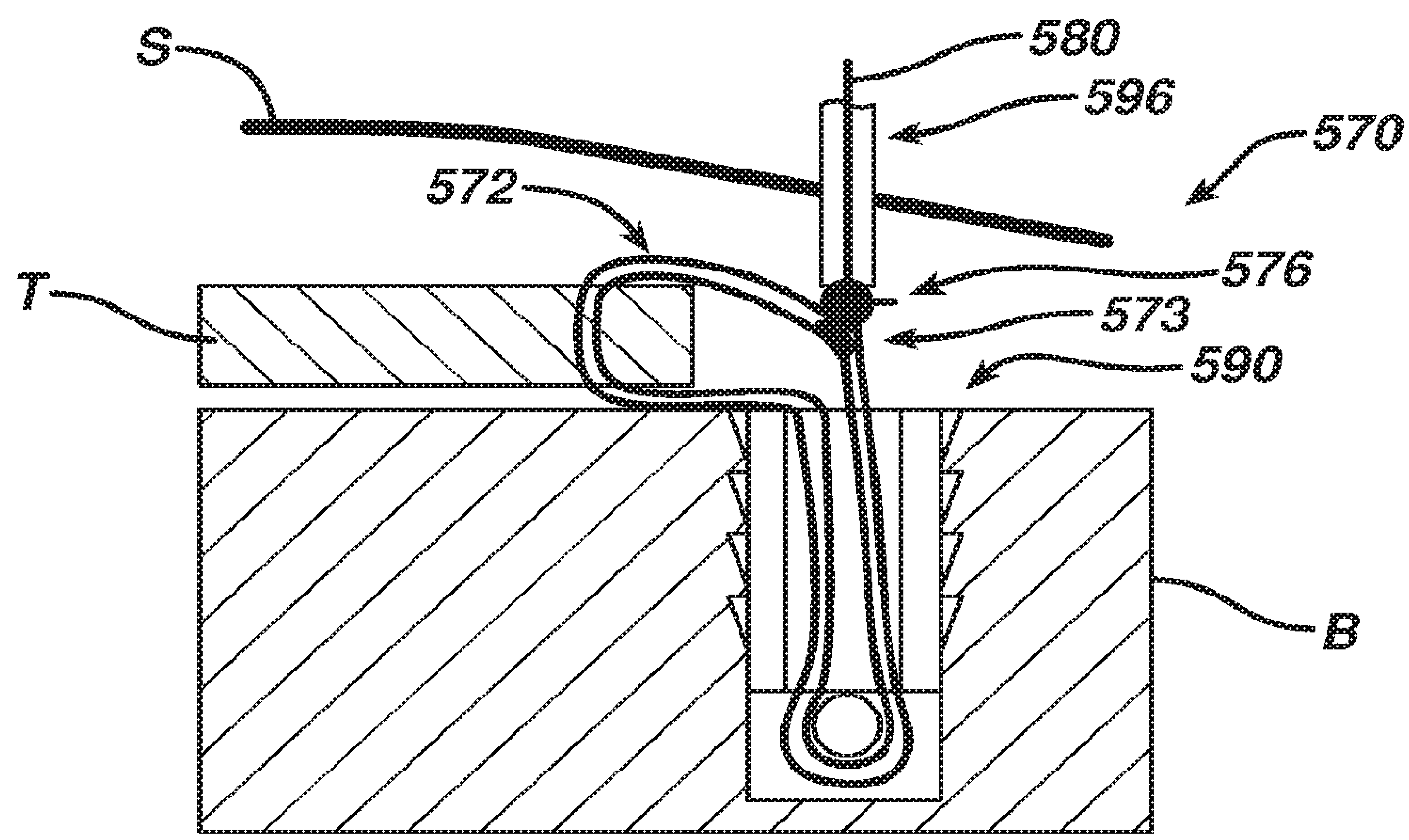

FIG. 50

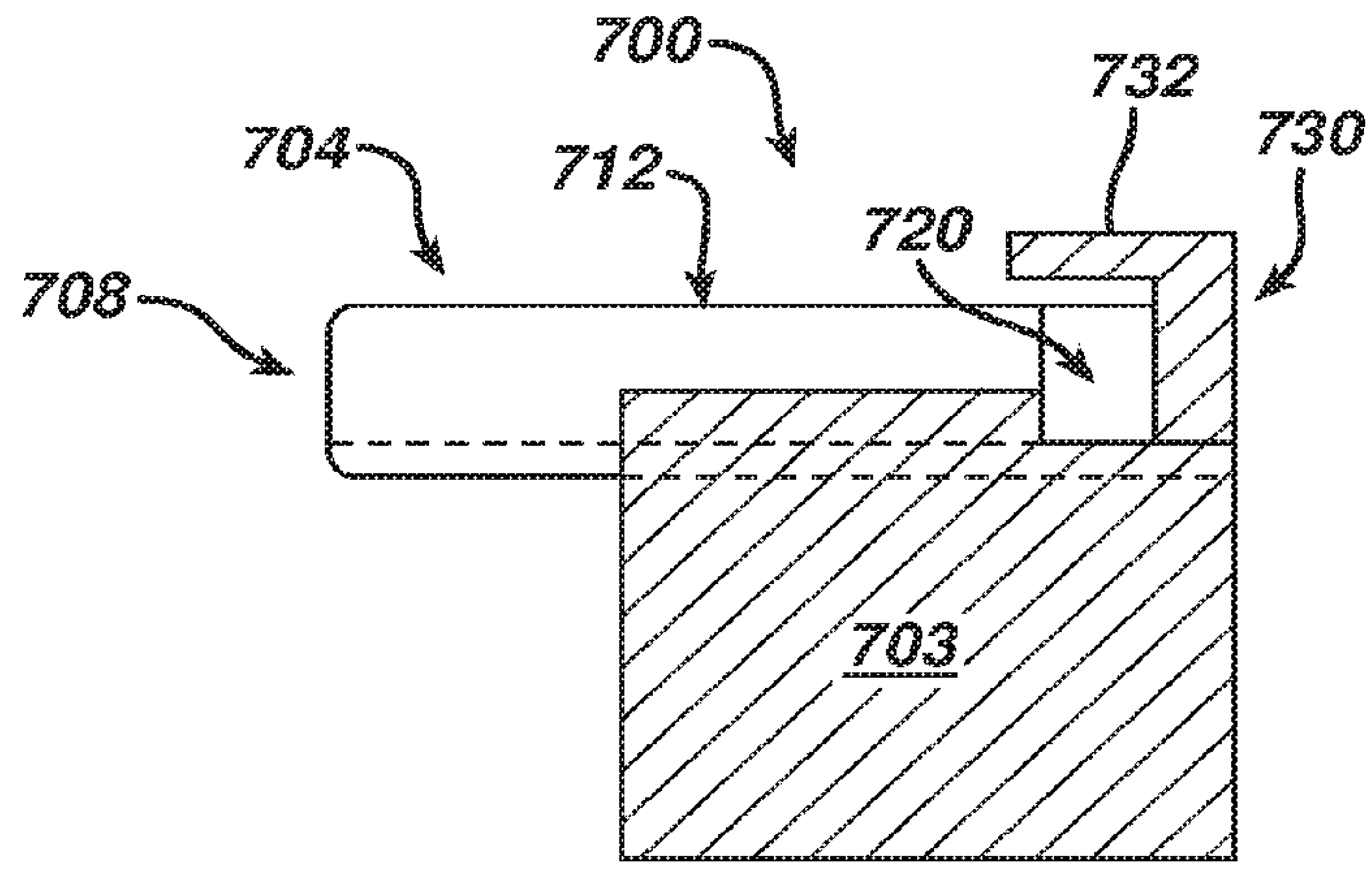

FIG. 53A

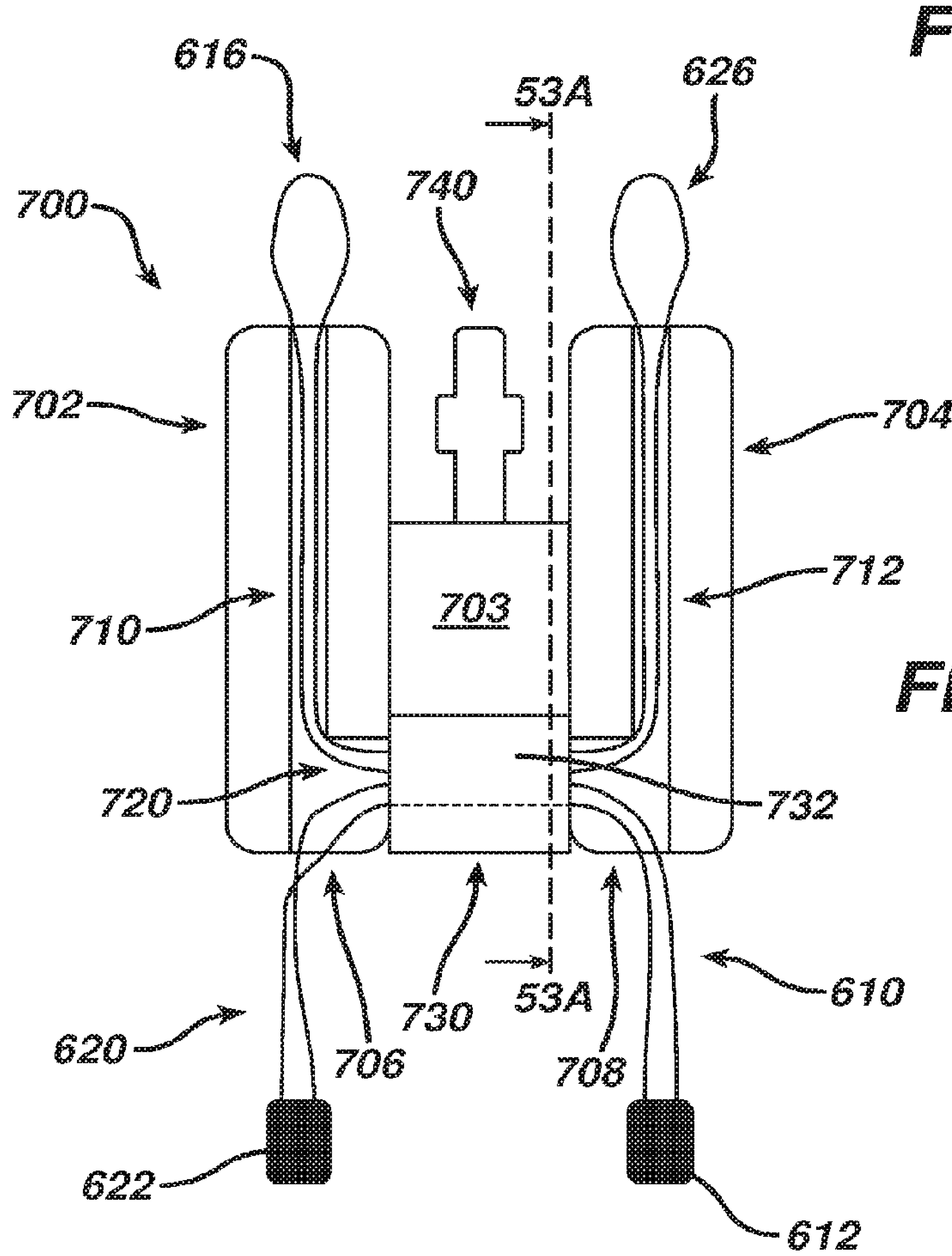

FIG. 53

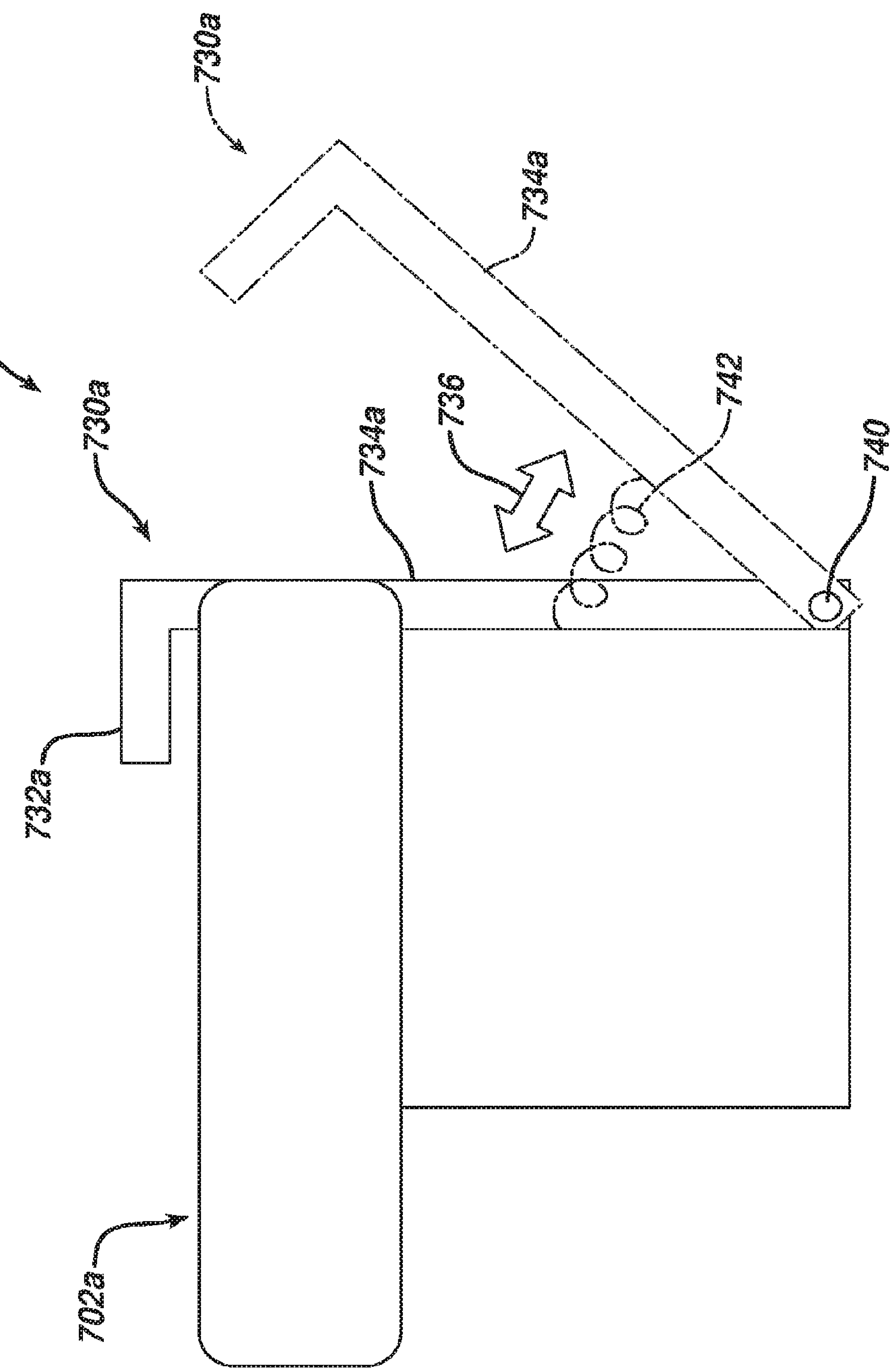

FIG. 54

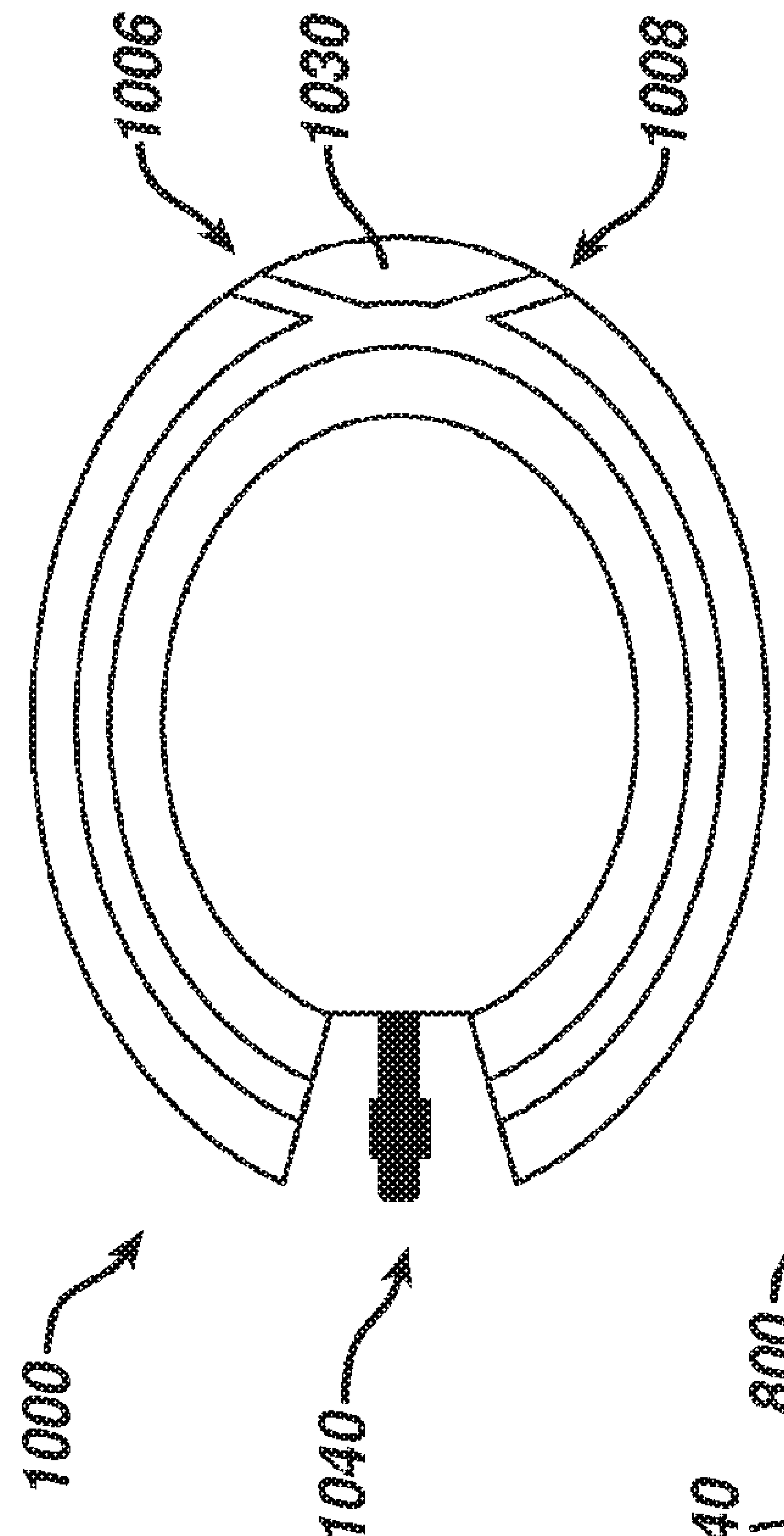

FIG. 57

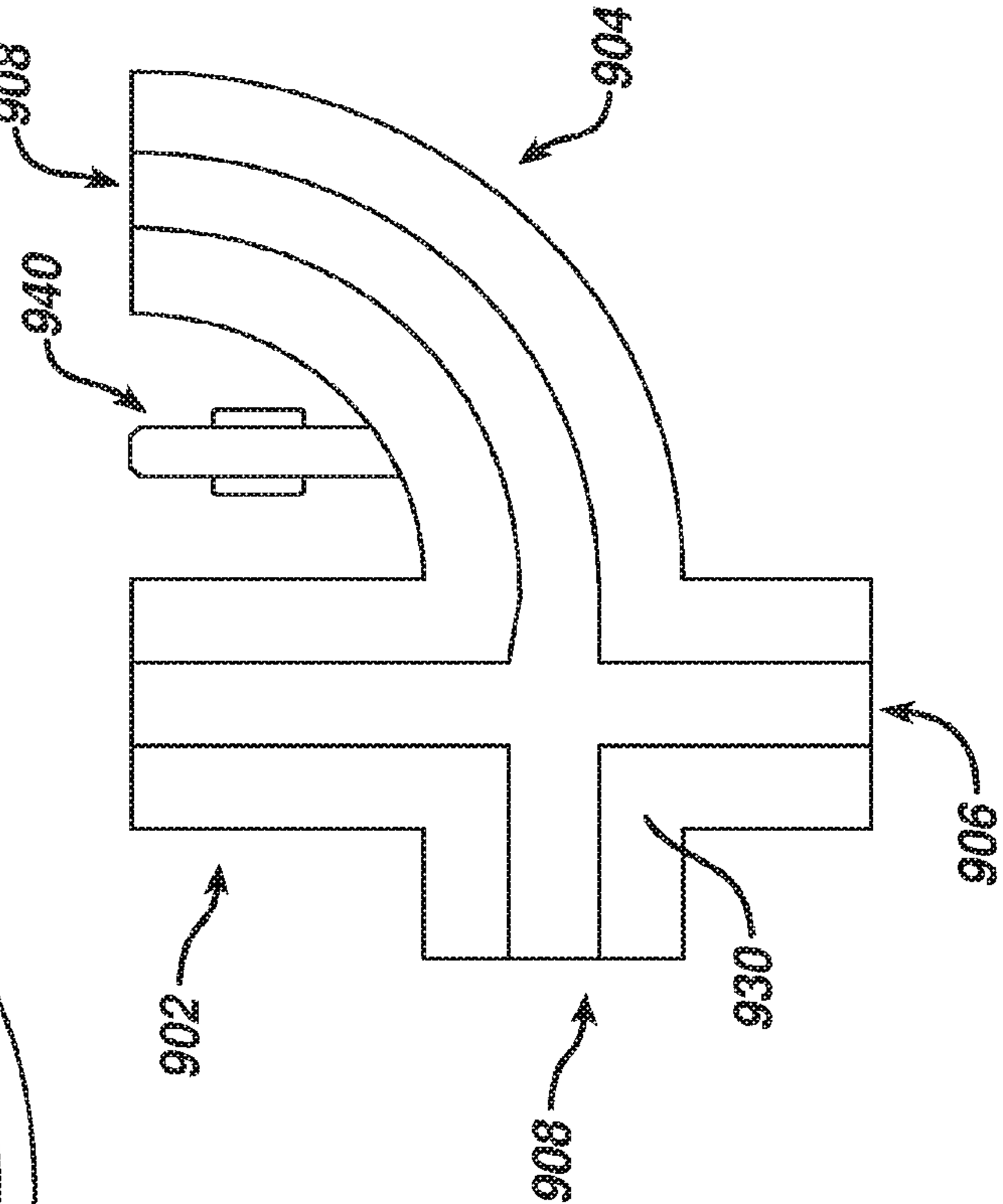

FIG. 56

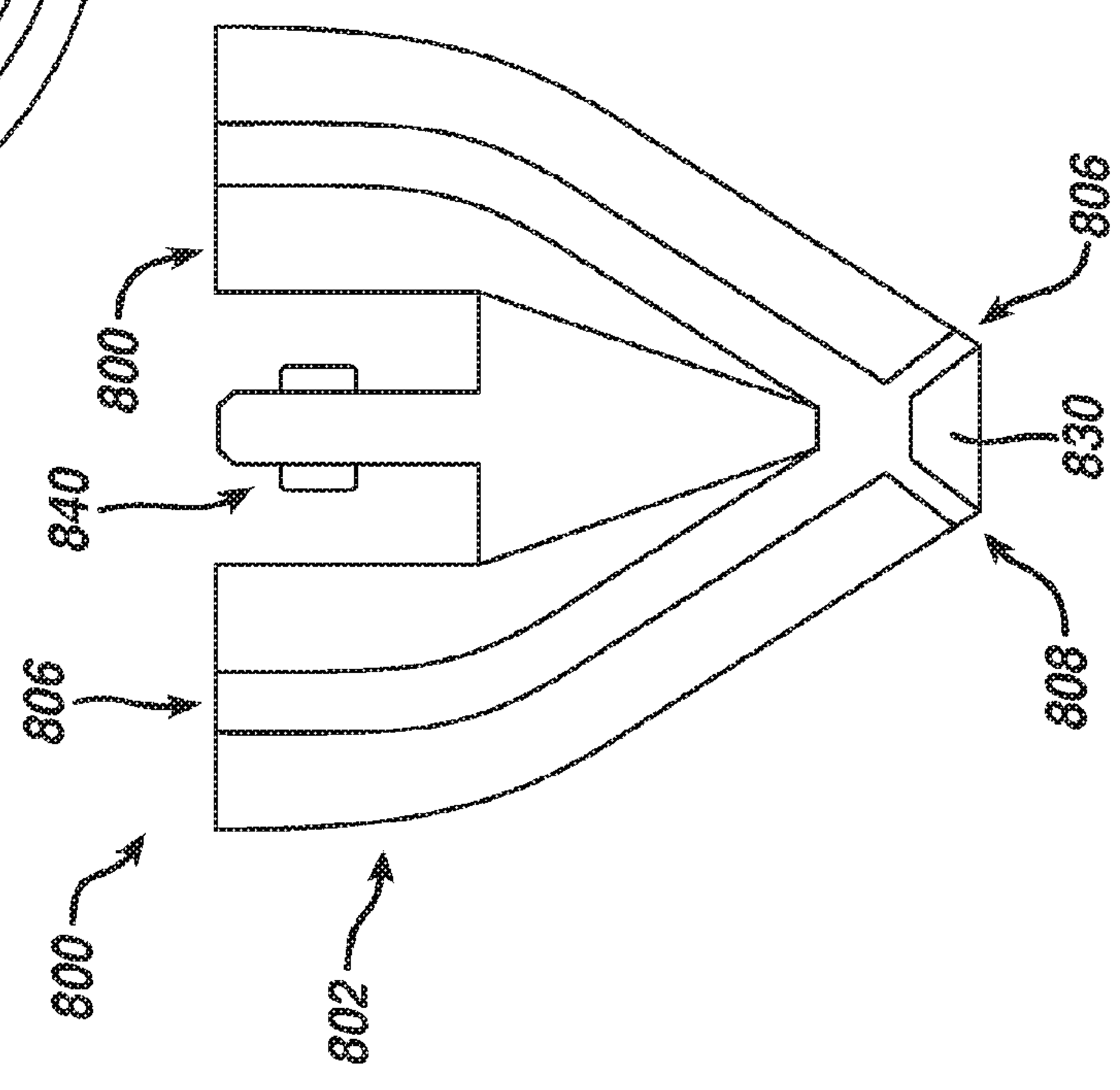

FIG. 55

SURGICAL FILAMENT SNARE ASSEMBLIES

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a divisional of and claims priority to U.S. application Ser. No. 13/218,810, filed Aug. 26, 2011, and entitled "SURGICAL FILAMENT SNARE ASSEMBLIES," which is a continuation-in-part of U.S. application Ser. No. 12/977,146, filed Dec. 23, 2010, entitled "ADJUSTABLE ANCHOR SYSTEMS AND METHODS," and which issued as U.S. Pat. No. 8,821,543 on Sep. 2, 2014. U.S. application Ser. No. 13/218,810 is also a continuation-in-part of U.S. application Ser. No. 12/977,154, filed Dec. 23, 2010, entitled "SURGICAL FILAMENT SNARE ASSEMBLIES," and which issued as U.S. Pat. No. 8,814, 905, on Aug. 26, 2014, which is a non-provisional of U.S. Application No. 61/416,562, filed on Nov. 23, 2010, and entitled "TISSUE ANCHOR WITH FRICTIONAL SUTURE ENGAGEMENT." All of the aforementioned applications and patents are hereby incorporated by reference in their entireties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to filament assemblies for securing tissue to bone and more particularly to adjustable tensioning of tissue independent of anchor fixation.

2. Description of the Related Art

A common injury, especially among athletes, is the complete or partial detachment of tendons, ligaments or other soft tissues from bone. Tissue detachment may occur during a fall, by overexertion, or for a variety of other reasons. Surgical intervention is often needed, particularly when tissue is completely detached from its associated bone. Currently available devices for tissue attachment include screws, staples, suture anchors and tacks.

Arthroscopic knot tying is commonly practiced in shoulder rotator cuff and instability procedures. Typically, an anchor loaded with suture is attached to bone first. The suture is normally slidably attached to the anchor through an eyelet or around a post, such that a single length of suture has two free limbs. One limb of the suture is passed through soft tissue to be repaired such as a tendon or labrum. The two ends of the suture are then tied to each other, thereby capturing the soft tissue in a loop with the anchor. Upon tightening the loop, the soft tissue is approximated to the bone via the anchor.

Surgeons typically tie the suture ends by first placing a surgical sliding knot such as the Tennessee Slider or Duncan Knot. After tightening the loop, a number of additional half hitches or other knots are tied. The additional knots are needed because a conventional sliding knot does not provide the necessary protection against loosening or slippage, especially when tension is placed primarily on the limbs of the loop. Generally accepted practice is to follow the sliding knot with at least three reversed half hitches on alternating posts of the suture.

Before one or more half hitches or other knots can be added to the sliding knot, however, there exists a potential for the sliding knot to slip, that is, for the loop to enlarge as the tissue places tension on the loop. This has been referred to as "loop security" and can reportedly occur even in the hands of very experienced surgeons. Sometimes, even fully-tied knots may slip. Further, the overall size of a conventional knot can be obstructive or intrusive, especially in tight joints, which may damage cartilage or other tissue by abrasion with the knot.

Suture anchor systems with sliding and locking knots for repairing torn or damaged tissue include U.S. Pat. No. 6,767,037 by Wenstrom, Jr. Other suture anchor systems suited especially for meniscal repair are disclosed in U.S. Pat. No. 7,390,332 by Selvitelli et al. and are utilized in the OmniSpan™ meniscal repair system commercially available from DePuy Mitek Inc., 325 Paramount Drive, Raynham, Mass. 02767.

There are a number of suture implant systems which proclaim to be "knotless", that is, to not require a surgeon to tie a knot during surgery. Many such systems control tension on tissue by the depth to which an anchor is driven into bone. U.S. Pat. Nos. 5,782,864 and 7,381,213 by Lizardi disclose certain types of suture anchors which capture a fixed-length loop of suture. Adjustable loop knotless anchor assemblies utilizing an anchor element inserted into a sleeve are described by Thal in U.S. Pat. Nos. 5,569,306 and 6,045,574 and in U.S. Patent Application Publication No. 2009/0138042. Other systems having clamps or other locking mechanisms include U.S. Pat. No. 5,702,397 by Goble et al. and U.S. Patent Application Publication No. 2008/0091237 by Schwartz et al.

It is therefore desirable to have robust yet adjustable fixation of tissue while minimizing both the number and size of knots to be tied by a surgeon, especially during arthroscopic repair procedures.

SUMMARY OF THE INVENTION

An object of the present invention is to meet or exceed the tissue tension control and holding power of currently available suture anchor assemblies for tissue repair procedures while reducing the number of half hitches or other knots to be tied by a surgeon.

Another object of the present invention is to reduce the size of the finished knot for the assembly.

A still further object is to simplify the overall knot tying process for the surgeon while providing enhanced loop security and knot security

Yet another object of the present invention is to provide incremental tensioning after anchor fixation.

This invention features a surgical filament snare assembly including an anchor capable of being fixated in bone and having a filament engagement feature. A first filament has a noose with first and second noose limbs connected, preferably slidably connected, to the filament engagement feature of the anchor. The first and second noose limbs emerge from the anchor as first and second free filament limbs which are capable of being passed through tissue to be repaired and then passable through the noose. The noose, such as one or more half-hitches, is capable of receiving the free filament limbs and strangulating them when tension is applied to at least one of the free filament limbs and the noose to enable incremental tensioning of the tissue after the anchor is fixated. Preferably, the snare assembly further includes a flexible sleeve joining at least some portion of the first and second free filament limbs to facilitate passing of the free filament limbs at least through the tissue as a single unit.

In preferred embodiments, the sleeve is formed from a braided suture. In certain embodiments, the first filament is a braided suture and a section of one of the first and second free filament limbs serves as the sleeve. In one embodiment, the sleeve section has fewer picks, preferably at least ten percent fewer, per unit length than the picks per unit length for the remainder of the first filament. In certain embodiments, the sleeve is positioned over the entire portion of the first and second filaments before implantation of the anchor in the patient, and in some embodiments the sleeve is further positioned beyond the filament engagement feature to cover at least some of the first and second noose limbs.

In some embodiments, the noose is retractable toward the anchor. A tool with at least one projection such as a tube may be included to assist passing the free filament limb through the noose. In certain embodiments wherein the noose is formed from at least one half hitch, the assembly includes at least two tubes capable of being removably inserted into different loops of the half hitch to provide passages for two ends of free filament limbs. In some embodiments, the tubes are joined together and have at least one handle for manipulating the tubes. Preferably, each tube is slotted to facilitate removal of the free filament limbs from the tubes.

This invention may be expressed as a method of surgically repairing tissue, preferably utilizing a sleeve, by selecting an anchor capable of being fixated in bone and having a filament engagement feature. A first filament is selected having a noose with first and second noose limbs connected, preferably slidably connected, to the filament engagement feature of the anchor. The first and second noose limbs emerge from the anchor as first and second free filament limbs which are capable of being passed through tissue to be repaired and then passable through the noose. Preferably a flexible sleeve, joining at least some portion of the first and second free filament limbs, is also selected to facilitate passing of the free filament limbs at least through the tissue as a single unit. The anchor is fixated in bone, and at least the sleeve is passed through the tissue to be repaired. At least the free filament limbs, preferably with the sleeve, are passed through the noose. The tissue is then tensioned as desired with the noose strangulating the free filament limbs when tension is applied to at least one of the free filament limbs and the noose to enable incremental tensioning of the tissue after the anchor is fixated. The sleeve is removed from the patient.

This invention also features a surgical filament snare assembly having an anchor capable of being fixated in bone and having a filament engagement feature, and a first filament having a fixed-length loop, capable of being passed through tissue and capable of being formed into a noose, on a first portion of at least a first limb and having a second portion. The assembly further includes a second filament having a collapsible loop slidably attached to the second portion of the first filament, the collapsible loop being formed by a sliding knot with a tensioning limb. The tensioning limb and the sliding knot are capable of being passed through the noose to enable incremental tensioning of the tissue after the anchor is fixated in bone, with the noose strangulating the collapsible loop when tension is applied to at least one of the free suture limb and the noose. At least one of the first filament and the second filament are slidably connected to the filament engagement feature of the anchor.

In some embodiments, the first filament is formed as a continuous loop, and the collapsible loop is slidably connected to the filament engagement feature.

This invention may also be expressed as a method of surgically repairing tissue with a fixed-length loop by selecting an anchor capable of being fixated in bone and having a filament engagement feature. A first filament is selected having a fixed-length loop, capable of being passed through tissue to be repaired and capable of being formed into a noose, on a first portion of at least a first limb and having a second portion slidably attached to a collapsible loop of a second filament, the collapsible loop being formed by a sliding knot with a tensioning limb, the tensioning limb and the sliding knot capable of being passed through the noose. The anchor is fixated in bone, and at least a portion of the fixed-length loop is passed through the tissue to be repaired. A portion of the fixed-length loop is formed into a Lark's Head knot to serve as the noose. The tissue is then tensioned as desired with the noose strangulating the collapsible loop when tension is applied to at least one of the tensioning limb, the sliding knot and the noose to enable incremental tensioning of the tissue after the anchor is fixated.

This invention further features a surgical filament snare assembly with a bone anchor and a first filament having a noose, formed from at least one half hitch, on a first portion of at least a first limb and having a second portion connected to the filament engagement feature of the anchor. The noose is capable of receiving at least two free filament limbs and strangulating them when tension is applied to at least one of the free filament limbs and the noose. Preferably, the assembly further includes a threader tool having at least two projections having distal ends capable of being removably inserted into different loops of the half hitch. Each projection defines a channel capable of receiving a portion of at least one free filament limb to pass it through a loop of the half hitch, and each projection further defines a slot communicating with the channel to facilitate removal of the filament limb from the tool.

In certain embodiments, the projections are tubes joined together with at least one handle for manipulation the tube. The proximal ends of the channels are connected by one of an intersection and a common passage, and the tool further includes a stop as a proximal portion of the one of the intersection and the common passage. In some embodiments, the stop is movable, and may include a spring to bias the stop toward the intersection or common passage. In yet other embodiments, the assembly further includes at least two suture passers having distal ends for engaging portions of the free filament limbs, and the suture passers capable of pulling the free filament limbs through the channels when proximal-directed force is applied to proximal ends of the suture passers.

This invention may yet also be expressed as a method of creating a surgical filament snare assembly by selecting a first filament having first and second ends, and forming at least one half hitch with a central opening in the first filament between the first and second ends. The first and second ends are passed through the central opening to define a noose with first and second noose limbs, and the half hitch is tightened to form a slidable knot for the noose. The first and second filament ends are passed through a filament engagement feature of an anchor to emerge from the anchor as first and second free filament limbs which are capable of being passed through tissue to be repaired and then passable through the noose, the noose strangulating the free filament limbs when tension is applied to at least one of the free filament limbs and the noose opening.

BRIEF DESCRIPTION OF THE DRAWINGS

In what follows, preferred embodiments of the invention are explained in more detail with reference to the drawings, in which:

FIG. **1** is a schematic side view of a surgical filament snare assembly according to the present invention having an anchor and a noose;

FIG. **1**A is a schematic side view of a hangman-type noose and FIG. **1**B is such a view of a half-hitch noose to be utilized according to the present invention;

FIG. **2** is a schematic side view of the assembly of FIG. **1** removably connected with a cannulated driver for initially fixating the anchor with a threader loop passed through the noose;

FIGS. **3**-**10** are schematic side views illustrating a process for capturing and tensioning tissue to the surgical filament snare assembly according to the present invention, with FIG. **8**A providing an example of a stopper knot shown in FIGS. **8**, **9** and **10**;

FIGS. **11** and **12** are perspective views of an alternative half-hitch noose in which multiple openings are utilized to strangulate two or more free filament limbs;

FIG. **13** is a perspective view of tubes to assist threading of free filament limbs through noose openings of FIG. **11**;

FIG. **14**A is a perspective view of a double-barreled, slotted threader device;

FIG. **14**B shows the device of FIG. **14**A being utilized to thread a noose;

FIGS. **15**-**19** illustrate different snare assemblies with retractable-noose configurations according to the present invention;

FIG. **20** is a schematic top view of multiple filaments that are passed through a single noose of a snare assembly according to the present invention;

FIG. **21** is an enlarged view of one construction of the configuration shown in FIG. **18**;

FIGS. **22**-**27** are schematic side views of the snare assembly of FIG. **18** utilized with another anchor placed through tissue to be repaired;

FIG. **28** is a perspective view of a snare assembly according to the present invention having a cannulated suture anchor;

FIG. **29** is a schematic view of a filament having a snare formed as a half hitch plus an additional throw with first and second noose filament limbs extending therefrom, and one embodiment of a sleeve, indicated in phantom, according to the present invention covering some of the first and second filament limbs;

FIGS. **30** and **31** are sequential views of the filament of FIG. **29** with the free filament limbs being passed through the noose to form a cinch noose, with a distal portion of a sleeve illustrated in FIG. **31**;

FIG. **32** is a schematic side view of the filament and sleeve combination of FIG. **29** implanted in a patient with an anchor;

FIG. **33** is a sketch of calculations for the relative lengths and positions of filament limbs relative to a sleeve for certain embodiments according to the present invention;

FIGS. **34**-**40** are schematic side views illustrating capture and tensioning of tissue utilizing another embodiment of sleeve and filament snare assembly according to the present invention;

FIG. **41** is a schematic side view of yet another sleeve and filament snare assembly according to the present invention;

FIGS. **42**A-**42**D is one exemplary technique for constructing the filament snare assembly of FIG. **41**;

FIGS. **43**-**46** are schematic side views of capture and tensioning of tissue utilizing the assembly of FIG. **41**;

FIGS. **47**-**50** are schematic side views of another snare assembly according to the present invention utilizing a lark's head knot, with FIG. **48**A depicting an alternative fixed-length loop;

FIG. **51** is a schematic top view of two suture passers, with the left passer placed diagonally over the right passer in preparation for becoming intertwined;

FIG. **52** shows the suture passers of FIG. **51** after the distal end of the left passer has been looped under and then over the right passer to form a simple half hitch;

FIG. **53** is a schematic top view of an improved threader tool according to the present invention with the suture passers of FIG. **52** held within channels by a fixed stop;

FIG. **53**A is a side cross-sectional view along lines **53**A-**53**A of FIG. **53**;

FIG. **54** is a schematic side view of an alternative threader tool with a movable stop; and

FIGS. **55**-**57** are schematic top views of yet other threader tools according to the present invention with different fixed-stop configurations.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

This invention may be accomplished by a surgical filament snare assembly including an anchor capable of being fixated in bone and having a filament engagement feature. A first filament has a noose, or a loop capable of being formed into a noose, on a first, proximal portion of at least a first limb and has a second portion connected, including slidably or fixedly connected, directly or indirectly, to the filament engagement feature of the anchor. The noose, such as one or more half-hitches, a Lark's Head knot, or a hangman-type noose, is capable of receiving at least one end of a free filament limb or a portion of another filament. The noose strangulates the free filament limb or other filament when tension is applied to the noose, to the free filament limb, and/or to the other filament.

In certain preferred constructions, at least a first free filament limb, which in some constructions is a length of the first filament and in other constructions is a second filament, is passed through tissue to be repaired and has at least one end passable through the noose to enable incremental tensioning of the tissue after the anchor is fixated in bone. The present application is directed to one or more improvements described below beginning with FIG. **29**.

Surgical filament snare assembly **10**, FIG. **1**, has an anchor **12** and a first filament **14**. In this construction, anchor **12** defines an internal passage **16** with a restricted opening **18** at its distal end **20** which serves as a filament engagement feature. At least one bone-engaging feature **22**, such as an external rib or helical thread, is located on the outer surface of anchor **12** between distal end **20** and proximal end **24**.

First filament **14** has a noose **30** at its proximal end and a fixed knot **32** at the distal end of filament post or stem **15** which interacts with restricted opening **18** to retain filament **14** in a fixed, permanently attached position. This arrangement may be referred to as the first filament **14** connected with the filament engagement feature **18**, which includes the phrase passing through the filament engagement feature **18**. Many conventional knots, such as a mulberry knot, can be utilized for fixed knot **32** as long as knot **32** has sufficient bulk to prevent pull-through at clinically desired tensions on noose **30**. A number of other types of filament engagements are described below. Stem **15** is kept as short as possible to maintain noose **30** close to anchor **12** even after it is collapsed as described below.

A well-known noose knot **33** is illustrated in FIG. **1**A in which first filament **14***a* has a hangman-type noose **30***a* at its proximal end and a fixed knot **32***a* at the distal end of stem **15***a*. Noose **30***a* has sliding noose knot **33** and defines an opening **34**. Noose knot **33** is tied by forming a flattened "S" or "Z" shape at the proximal end of filament **14***a* to form a large proximal loop to serve as the noose opening and a small loop spaced from the large loop. The doubled filament limbs are wrapped with the terminal end, also known as the working end. After typically four to eight wrapping turns, the terminal end is tucked through the small loop and trapped by pulling on whichever of the limbs of the large loop closes the small loop.

An alternative, simpler noose is illustrated for first filament **14***b*, FIG. **1**B, having a half hitch **35**, also referred to as a simple or overhand knot, tied to form noose **30***b* in the middle of filament limbs **36** and **38**. Multiple openings are created by the loops in half hitch **35** as described in more detail below, although central opening **37** is shown as a large single opening in FIG. **1**B. First filament limbs **36** and **38** are folded around half hitch **35** to form a double-stem arrangement, and the distal ends of first filament limbs **36** and **38** are joined in knot **32***b* after being passed through a suitable filament engagement feature on an anchor.

Noose efficiency is defined herein as the strangulation strength per unit tension applied on the noose, either by pulling on the filament on which the noose is tied or which otherwise carries the noose, or by pulling on one or more strands or limbs of filaments passing through the noose. A noose with lower internal friction in the noose knot will tend to have a higher noose efficiency.

One instrument for inserting anchor **12** into a hole drilled in bone is illustrated in FIG. **2**. Driver **40** has a distal end **42** removably insertable into passage **16**. Driver **40** is cannulated in this construction and has a lumen **44** with an optional threader filament **46** that passes through noose **30**. Use of a threader filament is optional, but may be desirable when noose **30** is spaced only a short distance from filament engagement feature **18**, in other words, when noose **30** is initially positioned close to or inside of anchor **12**.

In one procedure according to the present invention, anchor **12** is shown fixated within bone B, FIG. **3**, after driver **40** has been removed, in a hole **50** spaced at a desired distance from tissue T to be repaired. Noose **30** is in an initial open configuration. Threader filament **46** has a sufficient length to have both a threader loop **52** on a first limb, and a graspable portion on a second limb **54**, extend proximally above skin S while a mid-portion of threader filament **46** is slidably associated with noose **30**.

Continuing with this exemplary procedure, a second filament **60**, FIG. **4**, is threaded through tissue T using a suture passing instrument, a needle, or other tissue-penetrating technique chosen by a surgeon. Both free filament limbs **62** and **64** are brought together, typically above skin S, or at least outside of a joint space, and passed through threader loop **52**, FIG. **5**. Threader limb **54** is then pulled to thread both second filament limbs **62** and **64** through noose **30** as illustrated in FIG. **6** while noose **30** is in the initial open configuration. Alternatively, free filament limbs **62** and **64** are passed directly through noose **30** without using a threader filament.

When there is high noose efficiency, a light tug is sufficient to collapse noose **30** on the filament limbs **62** and **64** as shown in FIG. **7** to provide initial tensioning on the surgical filament snare assembly **10**. Generally, a higher noose efficiency can be utilized when one or more free filament limbs are threaded directly through noose **30** without using a threader filament, or are threaded using a tube or threader device such as shown in FIGS. **13**-**14**B below.

After initial or pre-tensioning of free filament limbs **62** and **64**, FIG. **7**, tension is released on limbs **62**, **64** and a slidable stopper knot **70**, FIG. **8**, is tied by the surgeon on limbs **62**, **64** above skin S. An enlarged view of one construction for stopper knot **70***a*, FIG. **8**A, shows a half hitch with an extra throw or turn, also known as a double overhand knot. A simple knot such as a single half hitch or overhand knot may be sufficient for some situations. Other suitable, more robust surgeon slidable knots with higher load capacity include the Tennessee Slider described in the Arthroscopic Knot Tying Manual (2005) available from DePuy Mitek, as well as the slidable, lockable knot by Wenstrom, Jr. in U.S. Pat. No. 6,767,037. Alternatively, a mechanical locking mechanism may be utilized where overall profile is not critical, especially away from a joint or other articulating surfaces.

Stopper knot **70** is advanced, typically using a knot pusher, until it contacts noose **30**, FIG. **9**. Tension generated between tissue T and anchor **12**, alone or together with pulling on one of the filament limbs **62** or **64**, causes noose **30** to further collapse, FIG. **10**, and strangulate the filaments. Stopper knot **70** augments the strangulation by transferring all tissue-generated tension on the stopper knot to the noose **30** and preventing slippage of filament limbs **62**, **64** into the noose knot. Accordingly, a self-cinching mechanism is created which inhibits loosening of the filaments. Tension can be increased incrementally in a ratchet-like effect by further advancing the stopper knot or pulling on one of filament limbs **62**, **64**.

Once satisfactory tissue tension has been achieved, one or more half hitches may be added to stopper knot **70** to fortify the loading capacity on the stopper knot and reduce the risk of loosening under adverse conditions. By comparison, conventional sliding knots typically are reinforced by at least two or three reversed half hitches placed on alternating posts. Due to the self-cinching effect of the present invention, fewer overall hitches or other knots are needed for stopper knot **70** to meet or exceed the load performance relative to conventional knot systems. The present invention thereby accomplishes a lower overall knot profile to handle a given load. Limbs **62**, **64** are trimmed as desired. The stopper knot also minimizes fraying of the filament ends over time.

Preferred materials for filaments **14** and **60** include various surgical sutures, typically size 0 to size 5, such as Orthocord™ suture commercially available from DePuy Mitek, and Ethibond™ suture available from Ethicon. Orthocord™ suture is approximately fifty-five to sixty-five percent PDS™ polydioxanone, which is bioabsorbable, and the remaining percent ultra high molecular weight polyethylene, while Ethibond™ suture is primarily high strength polyester. The amount and type of bioabsorbable material, if any, utilized in the first or second filament is primarily a matter of surgeon preference for the particular surgical procedure to be performed.

While the same type of suture, even identical suture, can be used for both first, noose filament **14** and second, tissue filament **60**, a suture having a lower abrasive property at its surface may be preferred by some surgeons for second filament **60**. The lower abrasive property can be achieved by a larger diameter, a softer composition, a softer braid, plait or strand pattern, or a combination of such characteristics. The term "braid" as utilized herein includes "plait" and other multifilament patterns.

The nooses illustrated in FIGS. **1**-**6** above have been described as having a single opening through which one or more free filament limbs are threaded. A simple half hitch or overhand-type "pretzel"-like knot is illustrated in FIG. **11** for noose **30***c* having multiple useful openings **80**, **82** and **84**.

Side openings **80** and **84** are formed by minor loops **81** and **83** of the half hitch knot in first filament limbs **36***c*, **38***c* while central opening **82** is formed by the major loop. Free filament limbs **62***c* and **64***c* are shown in FIG. **12** extending through side opening **80** and central opening **82**, respectively, although other combinations and permutations, such as using side openings **80** and **84**, or central opening **82** and side opening **84**, are also effective. Utilizing different areas or regions of the noose knot significantly increases effective strangulation and gripping on the free filament limbs. It is expected that utilizing multiple openings in the noose knot also minimizes any dependence of load carrying capacity on filament compliance characteristics. A simple, single half hitch stopper knot **70***c* is also illustrated in FIG. **12**.

While two or more threader filaments, or careful, potentially tedious manipulation by a surgeon, could be utilized to achieve the configuration shown in FIG. **12**, an alternative technique which avoids inadvertent noose collapse is shown in FIG. **13**. Tubes **90** and **92** have outer diameters suitable for sliding into the side openings formed by loops **81** and **83**. Filament limbs **36**, **38***c* are shown engaged with anchor **12***c*. Tubes **90** and **92** define passages **94** and **96**, respectively, through which free filament limbs **62***c* and **64***c* are threaded. Tubes **90** and **92** are then disengaged from noose **30***c* and drawn proximally along filament limbs **62***c* and **64***c* until they can be removed and discarded appropriately.

Double-barrelled threader device **100**, FIG. **14**A, has two threader tubes **102**, **104** which are joined together with a handle **106** and provide an even easier technique. In one construction, device **100** is molded as a monolithic unit using a polymer material. Tubes **102**, **104** have internal lumens **108**, **110**, respectively, also referred to herein as channels, with openings at both ends as well as slots **112**, **114**, respectively, which also run the entire length of tubes **102**, **104**. During use, tubes **102**, **104** are placed through loops **81***d*, **83***d*, FIG. **14**B, formed from first filament limbs **36***d*, **38***d*, and free filament limbs **62***d*, **64***d* are inserted through lumens **108**, **110**. Thereafter, limbs **62***d*, **64***d* are simply lifted through slots **112**, **114** to remove the fully-threaded filaments from the device **100**. One or more additional such tubes can be formed and utilized as desired. Also, the tubes **102**, **104** can be formed as “C” or “U” shapes in cross-section, with wider slots than illustrated.

There are a number of other configurations of snare assemblies according to the present invention which have one or more adjustable-length noose support stems or limbs that enable the noose to be retracted as desired toward an anchor. These configurations provide an additional level of control over the final filament positions and tensions. Snare assembly **120**, FIG. **15**, has a noose **124** formed at one end of a first filament **122** with a stem section **126** extending into anchor **130** to pass through ratchet-like one-way gate or clamping mechanism **132**. The remainder of filament **122** serves as a limb **128**, also referred to as a stem tail. Some examples of one-way mechanisms are disclosed in U.S. Pat. No. 5,702,397 by Goble et al., for example, which allow filament movement in only one direction.

As illustrated in FIG. **15**, anchor **130** is fixated in bone B. A second filament **134** is passed through tissue T and has free limbs **136** and **138** passed through noose **124**, initially positioned outside of a joint space surrounding tissue T. Limb **128**, also positioned outside of the joint space, is pulled to retract noose **124** toward mechanism **132**. Typically, the noose **124** is collapsed, limb **128** is trimmed, and then a procedure similar to that illustrated for FIGS. **7-10** above is utilized.

Snare assembly **140**, FIG. **16**, has first filament **140** having a noose **144** tied with two stem limbs **146** and **148** extending into anchor **150**. In this construction, anchor post **152** serves as a filament engagement feature to slidably attach filament **140** to anchor **150**. Filament stem tail limbs **154**, **156** extend out of a joint space, together with noose **144** in an initial configuration. Second filament **160** is passed through tissue T and then free limbs **162**, **164** are passed through noose **144** outside of the joint space.

In the procedure illustrated in FIG. **16**A, limbs **154** and **156** of first filament **142** are also passed through noose **144** and then pulled to collapse noose **144** about all four limbs **154**, **156**, **162** and **164** and to retract noose **144** toward filament engagement post **152**. One or more sliding knots are tied on limb pair **154**, **156** of the stem tails to adjust the proximity of noose **144** to the anchor **150** and then a simple knot is tied on free limbs **162**, **164** to adjust final tension on tissue T, although other combinations and permutations can be utilized within the scope of the present invention. Typically, the sliding knots are finished with one or more half hitches to “seal” or complete the fixation.

Snare assembly **170**, FIG. **17**, utilizes a single filament **172** both to secure noose **174** to anchor **180** and to tension tissue T. Stem limbs **176**, **178** pass into anchor **12** and slidably around filament engagement post **182** to emerge from anchor **180** as tail limbs **184**, **186** which are initially kept out of the joint space, along with noose **174**, when anchor **180** is fixated in bone B. In some constructions, anchor post **182** is an eyelet or a pulley pin. Free tail limbs **184**, **186** are passed through tissue T, in the same or different places or regions, and then through noose **174**. Noose **174** is collapsed and pulled into the joint space by applying light tension to one, or preferably both, of the tail limbs **184**, **186**. A simple stopper knot is tied between tail limbs **184**, **186** and pressed against the noose **174** while tensioning the limbs **184**, **186** to place a desired amount of tension on tissue T. The fixation is finalized by placing one or more half hitches against the stopper knot at noose **174**.

Snare assembly **190**, FIG. **18**, has functional similarities to snare assembly **120**, FIG. **15**, but achieves ratchet-like noose retraction without one-way gate or clamping mechanisms. Filament **192**, FIG. **18**, has a noose **194** with a stopper knot **196** at its terminal end to prevent pull-through and to resist fraying. A sliding knot **198** enables loop **200**, having loop limbs **202** and **204**, to be shortened toward anchor **205** when post limb **206** is pulled. Loop **200** passes around anchor saddle or post **207**. This and other adjustable loop, sliding knot configurations are described in more detail below in relation to FIGS. **21-27**.

Snare assembly **310**, FIG. **19**, includes a first filament **302** with a noose **304** and a loop **306** which is fixed in length, the overall length of filament **302** being subject to full collapse of noose **304**. A second filament **316** has a terminal end **318**, a sliding knot **322** retained at the distal end of anchor **312**, a post limb **320**, and an adjustable loop **324** formed by limbs **326**, **328**. This configuration is described in more detail below in relation to FIG. **28**.

While most of the embodiments herein have been described in relation to securing one or two filament limbs passed through a single place or region in a tissue T, this is not a limitation of the invention. Snare assembly **210**, FIG. **20**, has a first filament **211** with a noose **212** through which pass free limbs **214**, **216** and **218**, **220** of second and third filaments **222** and **224**, respectively. Noose **212** is engaged by stem **213** with anchor **215**. Filaments **222** and **224** pass through tissue regions R1 and R2, respectively. Multiple regions of a tissue, and potentially multiple types of sutures or other filaments, can thereby be secured using a single snare assembly according to the present invention.

One arrangement of the filament **192** for snare assembly **190**, FIG. **18**, is illustrated in FIG. **21** for snare assembly **190***a*. Noose **194***a* is formed merely by creating opening **232** in region **230** of filament **192***a* and passing filament **192***a* through itself. Loop **200***a* and sliding knot **198***a* are formed thereafter on post limb **206***a*. In this arrangement, any tension applied on stem **234**, such as by pulling post limb **206***a*, not only collapses noose **194***a* to strangulate objects passing through noose **194***a*, but also binds the portion of filament **192***a* passing through opening **232** upon itself. In other arrangements, a half hitch or other simple knot is tied at filament region **230**, and filament **192***a* is then looped through that simple knot. Stopper knot **196***a* such as a simple half hitch will prevent the terminal end from fraying or opening up, especially if a braided filament such as Orthocord™ suture is utilized for filament **192***a*.

An example of steps for manufacturing snare assembly **190**, FIG. **18**, utilizing suture as filament **192** is as follows. Tie stopper knot **196** and trim the tail of the terminal end. Loop the suture and pass it through itself in close proximity to the stopper knot **196** to achieve the noose arrangement illustrated in FIG. **21**, or tie a second half hitch in close proximity to the stopper knot and pass the suture through the half hitch to create the noose **194**, FIG. **18**. A thin mandrel or other object such as a pin may be placed through noose **194** to maintain patency. Sliding knot **198**, such as a bunt line half hitch knot, is tied in close proximity to the noose **194** and the suture is placed in sliding engagement with feature **207** of anchor **205**. Sliding knot **198** is then dressed or finalized as desired.

Conventionally, rotator cuff lateral row fixation involves spanning a suture bridge from medial anchors. Sutures are fixated with knotted or knotless anchors at the lateral row. Unthreaded anchors suffer more often than threaded anchors from anchor pull out, and suture slippage may occur at relatively low loads in many conventional procedures regardless of anchor type.

A presently preferred technique for rotator cuff double row repair is illustrated in FIGS. **22-27** utilizing the snare assembly of FIG. **18**. Medial row anchor **240**, FIG. **22**, is shown already embedded in bone B having cuff tissue T fixated at the medial row with suture **242**. Preferably, a threaded anchor is utilized for anchor **240**, and may be the same type of anchor as anchor **205**. Free suture limbs **244** and **246** are retracted out of the joint space, shown in FIG. **22** as extending beyond skin S. Threaded anchor **205**, FIG. **23** is then placed as a lateral row anchor in hole H independently of the medial row fixation. At this stage, collapsible loop **200** is long enough to enable sliding knot **198** and noose loop **194** to extend out of the joint space.

Suture limbs **244**, **246** from the medial row are then passed through noose **194**, FIG. **24**, preferably utilizing one of the threader devices described above. Any tension on suture limbs **244**, **246** will collapse noose **194** around them. The size of the threader tube may be selected to limit the migration of noose **194** from sliding knot **198**. Post limb **206** is then tensioned, FIG. **25**, in the proximal direction indicated by arrow **250** to retract sliding knot **198** into or in close proximity to anchor **205** and to place initial tension on suture bridge **258**.

A simple knot such as a half hitch is then tied between suture limbs **244**, **246** and pushed down against noose **194**, FIG. **26**, as sliding knot **260** while limbs **244** and **246** are pulled to further tension suture bridge **258** as desired. As second or more half hitches **262**, FIG. **27**, are added after suture bridge **258** has been properly tensioned to permanently lock the repair and the ends of suture limbs **244** and **246** are trimmed. Because a single noose can handle multiple pairs of sutures as described above in relation to FIG. **20**, additional suture bridges can be secured from multiple medial anchors as desired.

Adjustable suture snare assembly **310**, FIG. **28**, has a suture anchor **312** and a closed, fixed-length loop **306** of a first material **302**, which has a noose **304** tied at one end. A half hitch "pretzel"-like knot **305** is shown in this construction; another construction having a unitary fixed loop is disclosed in U.S. patent application Ser. No. 12/977,146 (Hernandez et al.), which is incorporated herein by reference. Loop **306** is captured by, in other words, is connected to, a second filament **316** having a terminal end **318**, a post limb **320**, a sliding bunt line half hitch knot **322**, and an adjustable loop **324** with loop limbs **326** and **328**. Second filament **316** may be considered as part of an adjustable filament engagement feature of anchor **12**, because filament **316** connects noose **304** to anchor **12**. In one construction, suture anchor **312** is similar to the cannulated suture anchor disclosed by Cauldwell et al. in U.S. Patent Application Publication No. 2008/0147063, incorporated herein by reference. In anchor systems utilized according to this sliding knot configuration of the present invention, however, it is not necessary to have a post-like suture-engaging member or other occluding element over which one or more sutures or suture limbs pass to serve as a restriction to proximal movement; in many constructions, it is sufficient to have a restricted opening **346** to prevent withdrawal of knot **322**.

Suture anchor **312** has a proximal end **330** and a distal end **332** with opposed distal arms **334** and **336** defining cut-out **338** between them. Passage **340** is an inner lumen which runs from proximal end **330** to distal cut-out **338**. Although knot **322** is shown extending beyond cut-out **338** in FIG. **28** for purposes of illustration, knot **322** preferably is seated against restricted opening **346** between arms **334** and **336**, or otherwise maintained at the distal end **332** by a cavity or other feature, during insertion of snare assembly **310** into a patient to minimize interference by the knot **322** with the bone-engaging feature **342**, or other exterior surface of anchor **312**, and the bone in which suture anchor **312** is fixated.

One or more bone-engaging features **342**, such as the helical thread illustrated in FIG. **28** or other features such as teeth, ridges, or other protrusions, are formed on the exterior of anchor **312** to enhance fixation in bone. Threads such as found on the Healix™ anchor available from DePuy Mitek Inc. are desirable. In another construction, the suture anchor rotates to toggle into bone at its proximal end to minimize withdrawal. In a number of constructions, a hole is formed in bone prior to anchor insertion; in other constructions, a suture anchor is inserted directly into bone. Further, one or more passages or channels may be formed on the exterior of the suture anchor, such as channel **344** illustrated in phantom, FIG. **28**, traversing bone-engaging element **342**.

It is a matter of surgeon preference whether a terminal end **318** is kept at a length sufficient to lie against the exterior of at least one bone-engaging feature **342** to be trapped against bone during insertion, or is trimmed to a shorter length. Further, a restriction such as restricted opening may be defined at least in part by engagement with bone when anchor **312** is fixated in bone to prevent knot **322** from moving with post limb **320** when tension is applied to post limb **320**.

One or more such distal extensions or other protrusions may be provided, similar in some constructions to Cauldwell et al. cited above or to U.S. Pat. No. 7,381,213 by Lizardi, also incorporated herein by reference. In yet other constructions, a cylindrical or otherwise circumferential cavity, bowl or countersink feature is provided at the distal end of the anchor to seat the knot **322** during insertion and fixation.

Slidable knot **322** has been described as a bunt line half hitch knot in some constructions, but other suitable knots will be readily apparent to those of ordinary skill in the suture tying art after reviewing the present invention. The term "slidable" as used herein is intended to include slidable, lockable knots as well as slidable knots, such as those described in the Arthroscopic Knot Tying Manual (2005) available from DePuy Mitek, as well as the slidable, lockable knot by Wenstrom, Jr. in U.S. Pat. No. 6,767,037.

Several improvements according to the present invention are illustrated in FIGS. **29**-**50**. A filament **400**, FIG. **29**, has a noose **402** and noose limbs **404** and **406**. Noose **402** defines a central opening **408** and secondary openings **410** and **412** formed from a half hitch plus one additional throw of limb **406** through central opening **408**. A flexible sleeve **414** is shown in phantom encapsulating some of limbs **404** and **406** in certain constructions, as described in more detail below.

FIGS. **30**-**31** illustrate the formation of a cinch noose **420**, also referred to as an improved cinch noose construct, having an opening **422**. The ends of free filament limbs **424** and **426** of filament **400** are passed through central opening **408**, as represented by arrows **427** and **429** in FIG. **30**, which draws noose limbs **424** and **426** therethrough. Noose **402** is then tightened, FIG. **31**, to form a slidable knot for cinch noose **420**. Alternatively, if a sleeve **414**, FIG. **29**, or sleeve **414***a*, FIG. **31**, is not utilized, or if such sleeve is removed after being passed through tissue to be tensioned, then one or both of free limbs **424**, **426** can be passed through one or both of openings **410**, **412**. One technique for utilizing improved cinch noose **420** is described below regarding FIGS. **34**-**40**.

Filament **400** with noose **402**, FIG. **29**, is shown in FIG. **32** slidably connected with anchor **430** as a snare assembly **432**, after placement through skin S into bone B of a patient. Sleeve **414** is positioned over and encapsulates the entire portion of first and second free limbs **424**, **426**, down substantially to, but not into, anchor **430** in this construction.

It is a realization of the present invention that joining together at least the free filament limbs improves suture management and reduces the possibility of suture entanglement or damage by instruments, especially when passed through a cannula. For example, a surgeon or other user need only grasp and pass one sleeve **414** through noose **402** to thereby manipulate free filament limbs **424**, **426** as a single unit. Additional convenience can be provided by perceptible indicators on one or more sleeves such as different markings, colors, diameters, braid or design patterns, or other tactile or visual indicia, especially if multiple tissue attachments or anchors are utilized, such as described above in relation to FIG. **20**. Preferably, the sleeves are removed and discarded after the filaments have been manipulated, as described below, so the perceptible indicators do not need to meet long-term implantation requirements.

One technique for calculating the relative lengths of filament **501** and sleeve **508** is illustrated in FIG. **33** for snare assembly **500** according to the present invention. A first factor is the distance, represented by arrow **502**, between noose **504**, in a substantially collapsed or reduced condition, and the distal end **506** of sleeve **508** over noose limbs **503** and **505**. One goal is to have distal end **506** accessible outside of a cannula after tissue is tensioned to enable latching or snagging of distal end **506** by a knot pusher or grasper to facilitate removal of sleeve **508**, as described in more detail below for other sleeves. Typical cannula lengths for hip and shoulder surgeries are between four to six inches, and the cannulas are typically placed approximately one-half inch from bone. The length of anchor **510** is included in the calculation.

For some constructions prior to implantation in a patient, sleeve **508** is twenty five inches in total length, with seven and one-half inches extending from the filament engagement feature of anchor **510** toward noose **504** as indicated by arrow **512**, with seventeen and one-half inches, arrow **514**, extending over and beyond free filament limbs **513** and **515** to proximal end **516** of sleeve **508**. In one construction, filament **501** has a total length of thirty six inches, or a folded length of eighteen inches, with sixteen and one-half inches, arrow **520**, extending from noose **504** to anchor **510**, and one and one-half inches, arrow **522**, as free limbs **513** and **515**. In another construction wherein filament **501** has a total length of sixty six inches and a folded length of thirty three inches, free filament limbs **513**, **515** extend sixteen and one-half inch as represented in phantom by arrow **524**. In either construction, marks can be placed on the filament noose limbs **503**, **505** nine inches from the center or middle, where noose **504** will be formed, to clearly indicate the proper positioning, arrows **502** and **512**, of distal end **506** of the sleeve **508** over filament **501** during preparation of snare assembly **500** for implantation.

A technique for utilizing the improved cinch noose **420**, FIG. **31**, with a sleeve **414***a* is shown in FIGS. **34**-**40** for another embodiment, represented by snare assembly **530** according to the present invention. In this construction, the sleeve **414***a*, shown with dashed lines, is slid over filament **400***a* and then loaded through anchor **532** to cover all of free limbs **424***a*, **426***a* and at least some of noose limbs **404***a*, **406***a*, preferably covering all of noose limbs **404***a*, **406***a* as they emerge above a cannula (not shown) passing through skin S during initial implantation of anchor **532** in bone B, FIG. **34** to assist in suture management and protection.

The proximal end of sleeve **414***a* is passed through tissue T, FIG. **35**, and then passed through cinch noose **420***a*, FIG. **36**. Alternatively, sleeve **414***a* can be removed after it is passed through noose **420***a* so that free limbs **424***a* and **426***a* can be passed directly through one or more openings in noose **420***a*. In either scenario for FIG. **36**, the noose **420***a* is then dressed, that is, collapsed, FIG. **37**, and then advanced near tissue T and tightened, FIG. **38**. The sleeve **414***a* is then removed entirely, FIG. **39**, and discarded according to standard procedures. The tissue repair is then finished with one or more half hitches **534** as desired, FIG. **40**.

Materials for sleeves include braided sutures such as Ethibond™ size 0 suture or Orthocord™ size 2 suture, also referred to as Orthocord™ #2 suture, which is typically braided at sixty picks per inch. For use as a sleeve, a more relaxed braid of approximately thirty to forty picks per inch is preferred, more preferably about 36 picks per inch. If the sleeve material is formed about a core, preferably that core is removed to facilitate insertion of the filament limbs, which may themselves be formed of typical suture such as Orthocord™ #0 suture or #2 suture braided at sixty picks per inch.

In yet another sleeve embodiment according to the present invention, one of the free filament limbs itself serves as the sleeve. For the construction illustrated in FIG. **41**, snare assembly **540** has a filament **542** of Orthocord™ #2 suture generally braided at sixty picks per inch with a noose **544** and noose limbs **545** and **546** that pass around filament engagement feature **550** of anchor **548**. Noose limbs **545** and **546** become free filament limbs **555** and **556**, respectively, extending proximally. At point **558**, however, a proximal section of limb **555** is braided at fewer picks per unit length, preferably more than ten percent fewer, more preferably at least twenty five percent fewer, to serve as sleeve **560** extending to its proximal end **562**. The other free filament limb **556** is threaded through sleeve **560** to emerge as proximal end **564** in this construction; in other constructions, the proximal end **564** lies wholly within sleeve **560**.

One technique for constructing snare assembly **540** is illustrated in FIGS. **42**A-**42**D. Filament **542** is shown in FIG. **42**A as initially manufactured with sleeve **560** being a section of suture formed with fewer picks per inch beginning at point **558** and extending to end **562**, preferably reduced from the standard 60 picks per inch to 36 picks per inch in this construction. Noose **544** is then created, FIG. **42**A, and then filament ends **562**, **564** are threaded through anchor **548** as shown schematically in FIG. **42**C. After a core element within sleeve section **560** has been removed, filament end **564** is then threaded within sleeve **560** using a needle-type insertion device to achieve snare assembly **540**, FIG. **42**D, with coaxial filament limbs in the sleeve section **560**. The length of sleeve **560** is likely to decrease as its diameter is expanded by the insertion device.

One procedure for utilizing snare assembly **540** is shown in FIGS. **43**-**45**. Anchor **548** is inserted into bone B, FIG. **43**, and then coaxial sleeve section **560** is passed through tissue T, FIG. **44**, and then noose **544**, FIG. **45**. Noose **544** is then collapsed toward tissue T, FIG. **46**, sleeve **560** is severed from filament **542**, and then filament **542** is tied and cut as described above for other embodiments to finish fixation of tissue T. The excess portion of filament **542**, including coaxial sleeve section **560**, is discarded.

Another embodiment according to the present invention is illustrated in FIGS. **47**-**50**. Snare assembly **570** has a fixed-length, preferably continuous loop **572** of a first filament which a surgeon or other user utilizes to form a Lark's Head knot, also known as a Bale Sling Hitch, to serve as a noose **573**, FIG. **48**, to grip a section of a second filament **574** as shown in FIGS. **49**-**50**.

Second filament **574**, FIG. **47**, has a collapsible loop **578** with a sliding knot **576** such as a sliding bunt line half hitch knot, a tensioning or post limb **580**, and a tag or terminal limb **581**. Collapsible loop **578** passes around filament engagement feature **592**, also referred to as a saddle **592**, of bone anchor **590**. In one construction, snare assembly **570** is manufactured in the condition shown in FIG. **47** and supplied to a user with sliding knot **576** already tied. To utilize snare assembly **570**, a hole **594** is formed in bone B and the anchor **590** is inserted to the position shown in FIG. **47**, and then continuous loop **572** is passed through tissue T.

After the noose **573** is formed with a Lark's Head knot, tail **580** and sliding knot **576** are passed through noose **573**, FIG. **49**. Noose **573** is then tightened against sliding knot **576**. A knot pusher **596**, FIG. **50**, assists in collapsing the loop **578** to tighten the snare assembly **570** to apply tension to tissue T. Depending on the overall length of first loop **572**, a portion of it may be drawn into anchor **590**.

Thus, when snare assembly **570** is supplied to a surgeon or other user with sliding knot **576** already tied, snare assembly **570** serves another example according to the present invention of a pre-formed, knot-less filament system which does not require the user to manipulate free limbs to tie knots during an operation. Adding to the benefits of snare assemblies according to the present invention, including high strength and loop security, low knot profile, ability to tension incrementally, and easy use with threaded anchors, providing a loop capable of forming a Lark's Head removes altogether the burden of tying a knot near or within a patient.

In other words, a first filament, preferably a continuous fixed-length suture loop, is slidably attached to a collapsible filament loop of a second filament having a preformed sliding knot. In another construction shown in FIG. **48**A, the fixed-length loop **572***a* is formed at one end of a first filament **601**, such as by pre-tying a first bowline knot **600**, and the other end of the first filament **601** is slidably attached to the second filament **574***a* with another, smaller loop **603**, such as formed by a second, smaller pre-tied bowline knot **602** through which the collapsible loop **578***a* passes. After the anchor is placed in bone, the continuous-loop end with bight **575***a* is passed through tissue. A Lark's Head knot is then created on the continuous loop **572***a*, which generates a very robust noose.

One or more tools can be utilized to assist creation of the constructs described above, especially if a half hitch is desired to be thrown on free filament limbs passing through different loops of a "pretzel" noose, that is, a noose with at least one half hitch that defines multiple loops through which the free filament limbs are passed. Improved threading tools and suture passers are illustrated in FIGS. **51**-**57** to automatically create a simple half hitch when two filament ends are pulled through loops of a noose.

Suture passer **620** is shown in FIG. **51** placed diagonally over suture passer **610**. Suture passer **610** has proximal tab or handle **612**, shaft **614** formed of wire or other flexible material, and opening **615** at distal end **616**. Suture passer **620** has proximal handle **622**, flexible shaft **624**, and an opening **625** at distal end **626**. Distal end **626** is looped under and around shaft **614** to create a simple half hitch **630**, FIG. **52**.

Intertwined suture passers **610** and **620** are shown held by threader tool **700** in FIG. **53**. Tool **700** has projections **702** and **704** which are substantially cylindrical tubes in this construction, whose distal ends are similar to tubes **102** and **104** of FIGS. **14**A-**14**B above. Each projection **702**, **704**, FIGS. **53**-**53**A, is supported by common handle **703** and has a longitudinal channel **706**, **708**, respectively, with slots **710**, **712** to facilitate placement of filaments or passers such as suture passers **610**, **620** into tool **700**, and to facilitate subsequent removal of filaments drawn into tool **700** by the passers. Tool **700** further defines a common passage **720**, formed in part by notches in the proximal walls of projections **702** and **704**, which interconnects the proximal portions of channels **706** and **708**. Half hitch **630**, FIG. **52**, lies within passage **720**, FIG. **53**, and is further held by fixed stop **730** with lip or overhang **732**, which is an inverted "L" shape in this construction. Tool **700** further includes a distal finger **740** in this construction to serve as a catch or post for one or more filaments during the threading procedure, such as to hold a cinch loop or other noose in position.

In another construction shown in side view in FIG. **54**, a tool **700***a* has a movable stop **730***a* with a strut **734***a* pivotally attached to handle **703***a* by pin **740** passing through the lower portion of strut **734***a*, or other type of hinge such as a living hinge. Tubular projection **702***a* is visible in this view. Stop **730***a* has a lip **732***a* supported by strut **734***a*. In one construction, a user manipulates stop **730***a* to hold or release suture passers by moving stop **730***a* toward or away from handle **703***a* as indicated by arrow **736**; stop **730***a* is shown in phantom in an open position after being moved away from handle **703***a*. In another construction, a spring **742**, also shown in phantom, biases stop **730***a* in one direction, preferably toward handle **703***a*. As a user pulls suture through the device, a certain amount of force causes stop **730***a* to overcome the biasing force of spring **742** and move away from handle **703***a* to assist release of the tied suture.

Several threader tools according to the present invention having intersecting channels are shown in top view in FIGS. **55**-**57**. A V-shaped tool **800**, FIG. **55**, has projections **802**, **804** with intersecting channels **806** and **808**, respectively, and a distal finger **840**. A proximal trapezoidal stop **830** holds suture passers in place as they pulled proximally. The distal portions of projections **802**, **804** become substantially parallel to each other to assist removal of the tied knot from tool **800**.

Tool **900**, FIG. **56**, has straight projection **902** and curved projection **904** that define channels **906** and **908**, respectively. Stop **930** forms a proximal corner at the intersection where sutures can be pulled proximally when force is applied at right angles to respective suture passers, which is expected to ease suture movement through the channels **906**, **908**.

Tool **1000**, FIG. **57**, is a horseshoe shape to reduce forces needed to pull sutures through the tool **1000**. Finger **1040** is positioned slightly below to distal opening of channels **1006**, **1008** to minimize obstruction of the suture threading process.

This invention may also be expressed as a surgical filament snare assembly with a bone anchor and a first filament having a noose, formed from at least one half hitch, on a first portion of at least a first limb and having a second portion connected to the filament engagement feature of the anchor. The noose is capable of receiving at least two free filament limbs and strangulating them when tension is applied to at least one of the free filament limbs and the noose. Preferably, the assembly further includes a threader tool having at least two projections having distal ends capable of being removably inserted into different loops of the half hitch. Each projection defines a channel capable of receiving a portion of at least one free filament limb to pass it through a loop of the half hitch, and each projection further defines a slot communicating with the channel to facilitate removal of the filament limb from the tool. Each slot has the same width as its corresponding channel in some embodiments and, in other embodiments, has a different width, typically a narrower width, than that of the corresponding channel.

In certain embodiments, the projections are tubes joined together with at least one handle for manipulation the tube. The proximal ends of the channels are connected by one of an intersection and a common passage, and the tool further includes a stop as a proximal portion of the one of the intersection and the common passage. In some embodiments, the stop is movable, and may include a spring to bias the stop toward the intersection or common passage.

In yet other embodiments, the assembly further includes at least two suture passers having distal ends for engaging portions of the free filament limbs, and the suture passers being capable of pulling the free filament limbs through the channels when proximal-directed force is applied to proximal ends of the suture passers. Preferably, the distal ends of the suture passers are intertwined in at least one half hitch to impart at least one half hitch to the free filament limbs when they are drawn through the tool. Different combinations selected from the group of an anchor, one or more filament constructs as described herein, a threader tool, and one or more suture passers can also be referred to as different kits according to the present invention.

Thus, while there have been shown, described, and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions, substitutions, and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit and scope of the invention. For example, it is expressly intended that all combinations of those elements and/or steps that perform substantially the same function, in substantially the same way, to achieve the same results be within the scope of the invention. Substitutions of elements from one described embodiment to another are also fully intended and contemplated. It is also to be understood that the drawings are not necessarily drawn to scale, but that they are merely conceptual in nature. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

Every issued patent, pending patent application, publication, journal article, book or any other reference cited herein is each incorporated by reference in their entirety.

What is claimed is:

1. A method of surgically repairing tissue, comprising:
- selecting an anchor capable of being fixated in bone and having a filament engagement feature;
- selecting a first filament having a noose with first and second noose limbs connected to the filament engagement feature of the anchor and emerging from the anchor as first and second free filament limbs which are capable of being passed through tissue to be repaired and then passable through the noose, and a flexible sleeve joining at least some portion of the first and second free filament limbs to facilitate passing of the free filament limbs at least through tissue as a single unit;
- fixating the anchor in bone;
- selecting at least the sleeve and passing it through the tissue to be repaired;
- passing at least the free filament limbs through the noose;
- tensioning the tissue as desired after the anchor is fixated in bone, the noose strangulating the free filament limbs when tension is applied to at least one of the free filament limbs and the noose; and
- removing the sleeve from the patient.

2. The method of claim **1** wherein the sleeve is formed from a braided suture.

3. The method of claim **1** wherein the first filament is a braided suture and a section of one of the first and second free filament limbs serves as the sleeve.

4. The method of claim **3** wherein the sleeve section has more than ten percent fewer picks per unit length than the picks per unit length for the remainder of the first filament.

5. The method of claim **1** wherein the sleeve is positioned over the entire portion of the first and second free filament limbs before implantation of the anchor in a patient.

6. The method of claim **5** wherein the sleeve is further positioned beyond the filament engagement feature to cover at least some of the first and second noose limbs.

7. The method of claim **1** wherein passing the free filament limbs through the noose includes passing them with the sleeve as a single unit.

8. The method of claim **1** wherein the noose is retractable toward the anchor.

9. The method of claim **1** wherein the noose is formed from at least one half hitch.

10. A method of creating a surgical filament snare assembly, comprising:
- selecting an anchor capable of being fixated in bone and having a filament engagement feature;
- selecting a first filament having first and second ends;

forming at least one half hitch with a central opening in the first filament between the first and second ends;

passing the first and second ends through the central opening to define a noose with first and second noose limbs;

tightening the half hitch to form a slidable knot for the noose; and

passing the first and second filament ends through the filament engagement feature of the anchor to emerge from the anchor as first and second free filament limbs which are capable of being passed through tissue to be repaired and then passable through the noose, the noose strangulating the free filament limbs when tension is applied to at least one of the free filament limbs and the noose opening.

11. The method of claim **10** further including adding a flexible sleeve joining at least some portion of the first and second free filament limbs to facilitate passing of the free filament limbs at least through tissue as a single unit.

12. The method of claim **11** wherein the first filament is a braided suture and a section of one of the first and second free filament limbs serves as the sleeve.

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